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OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

VOL. XXXIX—No. 5

AMERICAN SOCIETY OF CIVIL ENGINEERS FOUNDED 1852

May, 1913

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PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

(INSTITUTED 1852)

VOL. XXXIX—No. 5

MAY, 1913

Edited by the Secretary, under the direction of the Committee on Publications.

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NEW YORK 1913

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ON VALUATION OF PUBLIC UTILITIES: Frederic P. Stearns, H. M. Byllesby, Thomas H. Johnson, Leonard Metcalf, Alfred Noble, William G. Raymond, Jonathan P. Snow.

TO INVESTIGATE CONDITIONS OF EMPLOYMENT OF, AND COMPENSATION OF, CIVIL ENGINEERS: Alfred Noble, S. L. F. Deyo, Dugald C. Jackson, William V. Judson, George W. Tillson, C. F. Loweth, John A. Bensel.

TO CODIFY PRESENT PRACTICE ON THE BEARING VALUE OF SOILS FOR FOUNDATIONS, ETC.: Robert A. Cummings, Edward C. Shankland, Edwin Duryea, Jr., James C. Meem, Walter J. Douglas, Samuel T. Wagner, Frank M. Kerr.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

TELEPHONE NUMBER....................5913 Columbus.
CABLE ADDRESS..... ...."Ceas, New York."

Vol. XXXIX. MAY, 1913. No. 5.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PROCEEDINGS

This Society is not responsible for any statement made or opinion expressed in its publications.

SOCIETY AFFAIRS

CONTENTS

MINUTES OF MEETINGS

OF THE SOCIETY

April 16th, 1913.—The meeting was called to order at 8.30 P. M.; Vice-President J. Waldo Smith in the chair; Chas. Warren Hunt, Secretary; and present, also, 94 members and 10 guests.

A paper by C. J. Tilden, Assoc. M. Am. Soc. C. E., entitled "Kinetic Effect of Crowds," was presented by the Secretary. The paper was discussed orally by Messrs. Henry S. Prichard, R. D. Coombs, and J. B. French. The Secretary read communications on the subject from Messrs. Frazer C. Hilder and Henry H. Quimby.

A paper by Messrs. Arthur Taylor and Thomas Sanborn, entitled "Some Experiments with Mortars and Concretes Mixed with Asphaltic Oils," was presented by the Secretary. A discussion on the subject by Logan Waller Page, M. Am. Soc. C. E., was read by Mr. A. T.

Goldbeck, and the paper was discussed orally by Messrs. James Owen, W. J. Boucher, and A. T. Goldbeck.

The Secretary announced the following death:

GRIFFITH MORGAN ELDRIDGE, elected Associate Member, June 1st, 1892; Member, September 3d, 1902; died August 30th, 1912.

Adjourned.

May 7th, 1913.—The meeting was called to order at 8.35 P. M.; President George F. Swain in the chair; Charles Warren Hunt, Secretary; and present, also, 165 members and 22 guests.

The minutes of the meetings of March 19th and April 2d, 1913, were approved as printed in *Proceedings* for April, 1913.

The following resolution was presented by the Secretary in behalf of John H. Lewis, Assoc. M. Am. Soc. C. E.:

"*Moved:* That the Board of Direction of the American Society of Civil Engineers be and is hereby authorized and directed to appoint a special committee to investigate the advisability of drafting a National Water Law applicable to all navigable, interstate and other waters within the jurisdiction of the United States, and embracing all uses of water, and that such committee be directed to prepare a preliminary draft of such a law for submission at some regular meeting of the Society, if, in their judgment, it appears advisable."

On motion, duly seconded, the resolution was referred to the Board of Direction.

The following motion, offered by Allen Hazen, M. Am. Soc. C. E., was adopted:

"That the Board of Direction consider the matter of the appointment of a Special Committee to study the question of Floods, Flood Prevention, and other allied subjects."

A paper by H. de B. Parsons, M. Am. Soc. C. E., entitled "Tidal Phenomena in the Harbor of New York," was presented by the author, who illustrated his remarks with lantern slides. The paper was discussed by Messrs. T. Kennard Thomson, George A. Soper, Allen Hazen, James Owen, and E. F. Robinson.

On motion, owing to the lateness of the hour, and to the absence of the author, the paper entitled "Colorado River Siphon," by George Schobinger, Jun. Am. Soc. C. E., was not read, but was presented by title only.

The Secretary announced the election of the following candidates on May 7th, 1913:

AS MEMBERS

SHELDON BYRNE CLEMENT, North Bay, Ont., Canada
LEICESTER DURHAM, New Paltz, N. Y.
CHRISTOPHER HARRISON, Everett, Mass.

Edwin Wesley Hess, Clearfield, Pa.
Charles Edwin Jenkins, Easton, Pa.
Robert Vonartievelde Leeson, Topeka, Kans.
Edward Rowland Lewis, Duluth, Minn.
John Bell McRae, Ottawa, Ont., Canada
Bernard Herman Prack, Hamilton, Ont., Canada
Oscar Leonard Schlumpf, Pittsburgh, Pa.
William Craven Watson, West Haven, Conn.
George Henry Wells, New York City

As Associate Members

Richard Cecil Bayne, McKeesport, Pa.
William Bryant Bennett, Portland, Ore.
Alexander Blair, Summit, N. J.
Joseph Hugh Brooking, Springfield, Mo.
Arthur Culver, Buenos Aires, Argentine Republic
Ralph Bruère Daudt, Toledo, Ohio
Eugene Frank Deléry, New Orleans, La.
Fred Calvin Dunham, Spokane, Wash.
Frederick William Epps, Kansas City, Kans.
John Ashley Ferguson, Pittsburgh, Pa.
Frank Hoyt Fowler, Seattle, Wash.
Daniel Carlos Hayne, Indianapolis, Ind.
Thomas Stewart Johnston, Chicago, Ill.
Frances William Kellogg, Dobbin, W. Va.
Homer Virgil Knouse, Marble, Colo.
Clarence Herbert Kromer, Sacramento, Cal.
Henry Clinton McRae, Colgate, Md.
George Miles March, Wilson, N. C.
Horace Guy Merrick, La Crosse, Wis.
Charles Henry Moorefield, Washington, D. C.
Ben Stogden Morrow, Portland, Ore.
Wallace Cromwell Allen Palmer, Manila, Philippine Islands
Richard Edward Phillips, Albany, N. Y.
Fred Alexis Post-Nikov, Berkeley, Cal.
Harry Robinson, Atlantic City, N. J.
Robert John Ross, Hartford, Conn.
John Pierce Ryan, Hamilton, Cal.
Percy Augustus Shaw, Lancaster, Pa.
Louis Newton Sperry, Watertown, N. Y.
Jay Alvord Stilson, Detroit, Mich.
George Burrill Stone, Salt Lake City, Utah
Samuel Edwin Stott, Boston, Mass.
Frederick Peter Swartz, Springfield, Mo.
Franklin James Van Hook, Cincinnati, Ohio

William Tibbitts Webb, Newburgh, N. Y.
Walter Wallace Weir, North Yakima, Wash.
Andrew Perry Wenzell, Port Arthur, Ont., Canada

As Associate

Daniel Ellis Douty, New York City

As Juniors

Ira Leonard Collier, Olympia, Wash.
William Mack Eliot, Austin, Tex.
Harold Wiley Griswold, Tuscaloosa, Ala.
Irving Van Arnam Huie, New York City
Harry Lichtenstein, New York City
Howard Perry Michener, New Haven, Conn.
Howard Samuel Porter, Hartford, Conn.
William Henry Redlien, Richmond Hill, N. Y.
Charles Gilbert Reilly, Pittsburgh, Pa.
Edgar William Rossig, Weehawken, N. J.
Donald Hefley Rowe, Tacoma, Wash.
Edward Burchard Sandelands, Quintana, Tex.
Ernest Walker Sawyer, San Francisco, Cal.
Frederick Holman Waring, Cincinnati, Ohio

The Secretary announced the transfer of the following candidates on May 7th, 1913:

From Associate Member to Member

James Edwin Boatrite, South Bethlehem, Pa.
Brent Skinner Drane, Charlotte, N. C.
Paul Howes Norcross, Atlanta, Ga.
George Tilley Seabury, White Plains, N. Y.
Gabriel Roberts Solomon, Atlanta, Ga.
Murray Sullivan, Salt Lake City, Utah
Arthur Warren Tidd, White Plains, N. Y.
Garret Edward Tilt, New York City

From Associate to Member

Holger Struckmann, Kansas City, Mo.

From Associate to Associate Member

Jonathan Rhodes Smith, New York City

From Junior to Associate Member

Lester Bernstein, Baltimore, Md.
Louis Chevalier, Baltimore, Md.
Walter Louis Drager, Schenectady, N. Y.

William Dollison Faucette, Portsmouth, Va.
Sidney Twichell Harding, Washington, D. C.
Roger Tifft Holloway, New York City
Clarence Decatur Howe, Halifax, N. S., Canada
William Richard Hughes, Jr., Detroit, Mich.
David Clayton Johnson, Brooklyn, N. Y.
Glenn Vernon Rhodes, Oakdale, Cal.
Needham Everett Waddell, Kansas City, Mo.
Harland Clark Woods, Boulder, Colo.
Howard McClymonds Yost, Massillon, Ohio

From Junior to Associate

Stanley Phister Finch, Austin, Tex.

The Secretary announced the following deaths:

Charles Walker Raymond, elected Member, June 1st, 1892; died May 3d, 1913.

Henry William Vehrenkamp, elected Associate Member, June 5th, 1907; Member, June 30th, 1911; died April 25th, 1913.

William Belden Reed, Jr., elected Junior, December 1st, 1896; Associate Member, June 5th, 1907; died April 3d, 1913.

Charles Harry Tisdale, elected Associate Member, October 31st, 1911; died April 30th, 1913.

Adjourned.

OF THE BOARD OF DIRECTION

(Abstract)

May 7th, 1913.—President Swain in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Bush, Churchill, Edwards, Leonard, Ridgway, Smith, and Snow.

Acoustics of Auditorium.—A report was received from the Library Committee to which this matter had been referred, and it was resolved that the Board does not deem it necessary or expedient to take any further action in the matter.*

Conduct of Meetings and Presentation of Papers.—This matter again received careful consideration, and the Special Committee appointed to consider it was requested to prepare a draft of a Report of the Board on the subject for presentation to the Annual Convention.

Licensing of Engineers.—A report was received from the General Conference Committee of the five National Engineering Societies presenting the following Resolution recently adopted by that Conference Committee:

"That it is the sense of this Conference Committee that it is advisable that a Joint Committee of the National Engineering Societies be formed for the purpose of drafting a Bill for the Registration of Engineers, to be used, if necessary, to prevent vicious legislation; and that the members of this General Conference Committee be requested to report this action to their several Societies."

The Board declared itself in accord with this suggestion, and appointed Messrs. Robert Ridgway and Charles Warren Hunt as the Representatives of this Society on any Joint Committee which may be appointed by the other four National Societies.

Ballots for membership were canvassed, resulting in the election of 12 Members, 37 Associate Members, 1 Associate, and 14 Juniors, and the transfer of 13 Juniors to the grade of Associate Member, and 1 Junior to the grade of Associate.

Eight Associate Members and one Associate were transferred to the grade of Member, and one Associate was transferred to the grade of Associate Member.

Applications were considered, and other routine business transacted.

Adjourned.

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* For the substance of this report see page 346.

JOHN FRITZ, Hon. M. Am. Soc. C. E.*

"The Board of Directors of the JOHN FRITZ MEDAL FUND CORPORATION, learning with sorrow of the death of Mr. John Fritz at his home in South Bethlehem, Pennsylvania, on February 13th, 1913, in the ninety-first year of his age, desires to place upon its records this minute, upon the completion of his long and useful life of effective service to his Profession and his country.

"In 1902, when Mr. Fritz was approaching his eightieth birthday, his friends and admirers planned to give a dinner at which he should be the guest of honor. A dinner, however, was felt by many to be inadequate to commemorate so great a man, and to signalize the indebtedness of the profession of engineering for such a life so lived. A dinner, moreover, is soon forgotten and leaves no permanent record. Out of this thought grew the idea of creating a fund, by gift from the many who could attend and from the many more who could not be so assembled, the income from which should be used in honor of Mr. Fritz, to recognize and reward achievements in engineering similar to those which had made his life so valuable to the Profession and to the world. The result was a substantial subscription from the members of the four great engineering societies, and from other friends and professional associates of Mr. Fritz, and the creation of an incorporated body, to act as Trustees of the fund, and the judges who should award a medal for notable scientific or industrial achievement.

"The Directors of the corporation founded in April, 1903, to execute this trust, do not feel that they are called upon on this occasion to make any extended reference to the professional achievements of Mr. Fritz, or to his fine character and the charm of his personality. This has been done elsewhere and by competent hands. But it will be proper to refer to the influence which the achievements and the character of the man whose name it bore has always had in the award of the John Fritz Medal. The recipient of it must have done some notable thing such as would have commended itself to the clear-headed judgment, and the kindly approval, of the man in whose honor the Board was created to act. It is the wish and the ambition of the Board of Award that it shall ever maintain the standard set by the life and achievements of Mr. Fritz in the men and their achievements, to whom the John Fritz Medal is awarded.

"The Board feels that the ordinary phrases of corporate action would be inappropriate upon the termination of such a splendid life by the summons to yet higher service, especially when such Board exists for the specific purpose of perpetuating and making influential

* Action taken by the John Fritz Medal Board of Award which is made up of representatives of the American Society of Civil Engineers, the American Institute of Mining Engineers, the American Society of Mechanical Engineers, and the American Institute of Electrical Engineers.

the noble spirit and high ideals of such a life by rewarding achievement in its field.

"What it may properly do is to express thankfulness that the life was spared so long, and to record its pledge that this Board will ever strive so to carry out its purpose that the name and the life of John Fritz may be powers for good through the years to come and in the fields of Applied Science in which he made himself so eminent, and that it shall thus help to keep bright the luster of that name.

"*Resolved:* That this minute be spread in full upon the records of the John Fritz Medal Fund Corporation and that copies of it be sent to the secretaries of the four engineering societies represented on that body for such publication as they may deem proper.

"Respectfully submitted,

"Frederick R. Hutton,
"Charles Kirchhoff,
"Special Committee."

ACOUSTICS OF THE SOCIETY AUDITORIUM

At the Annual Meeting of 1913, the following action was taken referring to the Auditorium:

"That the Board of Direction be requested to employ the best talent that is available, and do something to make it more satisfactory to the hearers in this room and to the speakers also."

This matter has been under careful consideration for some time, and expert advice has been secured which in effect is as follows: That the room is not at all bad acoustically, and that it is a question whether the slight annoyance which exists is worth removing. If the walls were subjected to an additional treatment by the placing of specially prepared felt in the vertical panels and covering this with burlap, it would tend to make the room better acoustically. This work, if undertaken, would cost $565.

The Board of Direction, at its meeting of May 7th, 1913, after carefully considering the matter, decided that it was not necessary or advisable to do anything further in this matter.

ANNOUNCEMENTS

The House of the Society is open from 9 A. M. to 10 P. M., every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

FUTURE MEETINGS

June 4th, 1913.—8.30 P. M.—This will be a regular business meeting. Two papers will be presented for discussion, as follows: "The Philosophy of Engineering," by Maurice G. Parsons, Jun. Am. Soc. C. E.; and "The Elevation of the Tracks of the Philadelphia, Germantown and Norristown Railroad, Philadelphia, Pa.," by Samuel Tobias Wagner, M. Am. Soc. C. E.

Mr. Parsons' paper was printed in April, 1913, *Proceedings,* and Mr. Wagner's paper is published in this number of *Proceedings.*

September 3d, 1913.—8.30 P. M.—A regular business meeting will be held, and two papers will be presented for discussion, as follows: "The Storage of Flood Waters for Irrigation: A Study of the Supply Available from Southern California Streams," by A. M. Strong, Assoc. M. Am. Soc. C. E.; and "Modern Pier Construction in New York Harbor," by Charles W. Staniford, M. Am. Soc. C. E.

These papers are printed in this number of *Proceedings.*

September 17th, 1913.—8.30 P. M.—At this meeting a paper by J. C. Ulrich, M. Am. Soc. C. E., entitled "The Prewitt Reservoir Proposition," will be presented for discussion.

This paper is printed in this number of *Proceedings.*

October 1st, 1913.—8.30 P. M.—A regular business meeting will be held, and a paper by W. J. Wilgus, M. Am. Soc. C. E., entitled, "Physical Valuation of Railroads," will be presented for discussion.

This paper is published in this number of *Proceedings.*

NEW ORLEANS MEETING

The Meeting of the Society scheduled for October 15th, 1913, will be held in New Orleans, La.

The object of making the announcement of this meeting at the present time is to give ample notice to the membership; a later announcement, covering the matter more in detail, will be published in the August number of *Proceedings,* and quite possibly may be issued to the membership in the form of a circular.

It has been realized for some time that, with only one Annual Convention during each year, it is almost impossible to hold meetings which will be accessible to the rapidly growing membership, and there are some localities in which it is perhaps not desirable to hold a Summer Convention. It is hoped that by this plan one or more additional Society Meetings can be held each year, and that these will serve to bring the somewhat widely scattered membership into closer touch with the Society and its work.

The only announcement as to the programme that can be made at the present time is that a paper by W. E. Fuller, M. Am. Soc. C. E., entitled "Flood Flows," will be presented at that meeting. Mr. Fuller's paper is printed in this number of *Proceedings*.

ANNUAL CONVENTION

The Forty-fifth Annual Convention of the Society will be held at Ottawa, Ont., Canada, from June 17th to 20th, 1913, inclusive.

The general arrangements for the Convention are in the hands of the following Committees:

COMMITTEE OF THE BOARD OF DIRECTION

Charles H. Rust, *Chairman,*

Henry W. Hodge. Chas. Warren Hunt.

LOCAL COMMITTEE

Chas. H. Keefer, *Chairman,*

W. H. Breithaupt,	H. Holgate,	John Kennedy,
S. J. Chapleau,	J. A. Jamieson,	William McNab,
C. R. F. Coutlee,	Phelps Johnson,	C. H. Mitchell,
A. R. Dufresne,	T. C. Keefer,	H. R. Safford,
G. H. Duggan,	H. G. Kelley,	W. F. Tye,
Sir Sandford Fleming,		G. W. Volckman.

A preliminary circular has been sent to all members, and, as soon as arrangements have been completed, an additional circular will be issued.

INTERNATIONAL ENGINEERING CONGRESS IN 1915

In connection with the Panama-Pacific International Exposition, which will be held in San Francisco in 1915, there will be an International Engineering Congress, in which engineers throughout the world will be invited to participate.

The Congress is to be conducted under the auspices of the five National Engineering Societies, namely: the American Society of Civil Engineers, the American Institute of Mining Engineers, the American Society of Mechanical Engineers, the American Institute of Electrical Engineers, and the Society of Naval Architects and Marine Engineers.

These Societies, acting in co-operation, have appointed a permanent Committee of Management, consisting of the Presidents and Secretaries of each of these Societies, and eighteen members resident in San Francisco.

As thus officially constituted, the personnel of the Board is as follows:

Representing the American Society of Civil Engineers:

George F. Swain, *President,*
Charles Warren Hunt, *Secretary,*
Arthur L. Adams,
W. A. Cattell,
Charles Derleth, Jr.,
Charles D. Marx.

Representing the American Society of Mechanical Engineers:

W. F. M. Goss, *President,*
Calvin W. Rice, *Secretary,*
W. F. Durand,
R. S. Moore,
T. W. Ransom,
C. R. Weymouth.

Representing the American Institute of Mining Engineers:

Charles F. Rand, *President,*
Bradley Stoughton, *Secretary,*
H. F. Bain,
Edward H. Benjamin,
Newton Cleaveland,
William S. Noyes.

Representing the American Institute of Electrical Engineers:

Ralph Davenport Mershon, *President,*
F. L. Hutchinson, *Secretary,*
J. G. De Remer,
A. M. Hunt.

Representing the Society of Naval Architects and Marine Engineers:

Robert M. Thompson, *President,*
D. H. Cox, *Secretary,*
George W. Dickie,
William R. Eckart,
H. P. Frear.

The Committee has effected a permanent organization, with Professor William F. Durand as Chairman, and Mr. W. A. Cattell as Secretary-Treasurer, and has established executive offices in the Foxcroft Building, 68 Post Street, San Francisco.

The ten members of the Committee, consisting of the Presidents and Secretaries of the five National Societies, will constitute a Committee on Participation, through which all invitations to participate in the Congress will be issued to Governments, Engineering Societies, and individuals.

The personnel of this Committee is as follows:

Committee on Participation:

Charles F. Rand, *Chairman,*
Charles Warren Hunt, *Secretary,*

D. H. Cox,	Calvin W. Rice,
W. F. M. Goss,	Bradley Stoughton,
F. L. Hutchinson,	George F. Swain,
Ralph Davenport Mershon,	Robert M. Thompson.

The actual management of the Congress and the work of securing and publishing papers will be in charge of the members of the Committee resident in San Francisco. The work of the Resident Members has been assigned to different sub-committees, and Chairman Durand has made the following appointments:

Executive Committee:

W. F. Durand, *Chairman, Ex-officio,*
W. A. Cattell, *Secretary, Ex-officio,*
E. H. Benjamin, W. G. Dodd, A. M. Hunt.

Finance Committee:

W. G. Dodd, *Chairman*, Newton Cleaveland, R. S. Moore.

Papers Committee:

A. M. Hunt, *Chairman*,

A. L. Adams,	G. W. Dickie,	C. D. Marx,
H. F. Bain,	W. R. Eckart,	C. R. Weymouth.

Publicity Committee:

W. A. Cattell, *Chairman*,

C. Derleth, Jr., W. S. Noyes, T. W. Ransom.

Local Affairs Committee:

E. H. Benjamin, *Chairman*, J. G. De Remer, H. P. Frear.

The Honorary Officers of the Congress will consist of a President and a number of Vice-Presidents selected from among the most distinguished engineers of this and foreign countries.

The papers presented at the Congress will naturally be divided into groups or sections. During the Congress each section will hold independent sessions, which will be presided over by a chairman eminent as a specialist in the branches of engineering covered by his section.

The scope and magnitude of the Congress has not as yet been definitely fixed, but it is intended that it shall be the largest and most comprehensive Engineering Congress ever held; that the progress made in every branch of the Profession in the past decade be thoroughly reviewed, and the latest developments and most approved practices, accurately stated by the leading engineers of the world.

The papers, which will be collected and published by the Congress, should form an invaluable engineering library, and it is intended that this publication shall be in such form and at such cost as to become available to the greatest possible number.

The various committees are now actively at work, and it is hoped that further and more definite announcements as to the membership fees, schedules of papers, etc., can be made in the very near future.

SEARCHES IN THE LIBRARY

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

In reference to this work, the Appendices* to the Annual Reports of the Board of Direction for the years ending December 31st, 1906, and December 31st, 1910, contain summaries of all searches made to date.

PAPERS AND DISCUSSIONS

Members and others who take part in the oral discussions of the papers presented are urged to revise their remarks promptly. Written communications from those who cannot attend the meetings should be sent in at the earliest possible date after the issue of a paper in *Proceedings.*

All papers accepted by the Publication Committee are classified by the Committee with respect to their availability for discussion at meetings.

Papers which, from their general nature, appear to be of a character suitable for oral discussion, will be published as heretofore in *Proceedings*, and set down for presentation to a future meeting of the Society, and, on these, oral discussions, as well as written communications, will be solicited.

All papers which do not come under this heading, that is to say, those which from their mathematical or technical nature, in the opinion of the Committee are not adapted to oral discussion, will not be scheduled for presentation to any meeting. Such papers will be published in *Proceedings* in the same manner as those which are to be presented at meetings, but written discussions, only, will be requested for subsequent publication in *Proceedings* and with the paper in the volumes of *Transactions.*

* *Proceedings*, Vol. XXXIII, p. 20 (January, 1907); Vol. XXXVII, p. 28 (January, 1911).

LOCAL ASSOCIATIONS OF MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

San Francisco Association

The San Francisco Association of Members of the American Society of Civil Engineers holds regular bi-monthly meetings, with banquet, and weekly informal luncheons. The former are held at 6 P. M., at the Palace Hotel, on the third Friday of February, April, June, August, October, and December, the last being the Annual Meeting of the Association.

Informal luncheons are held at 12.15 P. M. every Wednesday, and the place of meeting may be ascertained by communicating with the Secretary of the Association, E. T. Thurston, Jr., M. Am. Soc. C. E., 713 Mechanics' Institute, 57 Post Street.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in San Francisco, and any such member will be gladly welcomed as a guest.

(Abstract of Minutes of Meeting)

February 21st, 1913.—The meeting was called to order; President Wing in the chair; E. T. Thurston, Jr., Secretary; and present, also, 60 members.

President Wing delivered his Inaugural Address.

A paper by H. A. Campbell, Assoc. M. Am. Soc. C. E., entitled "Some Glimpses and Criticisms of Public Work in San Francisco," was presented by the author, who illustrated his remarks with stereopticon views of various types of municipal work.

Adjourned.

Colorado Association

The meetings of the Colorado Association of Members of the American Society of Civil Engineers are held on the second Saturday of each month, except July and August. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary, Gavin N. Houston, M. Am. Soc. C. E., 409 Equitable Building, Denver, Colo. The meetings are usually preceded by an informal dinner. Members of the American Society of Civil Engineers will be welcomed at these meetings.

Weekly luncheons are held on Wednesdays, and, until further notice, will take place at the Colorado Traffic Club.

Visiting members are urged to attend the meetings and luncheons.

(Abstract of Minutes of Meetings)

March 8th, 1913.—The meeting was called to order; President Ketchum in the chair; G. N. Houston, Secretary; and present, also, 17 members and 17 guests.

President Ketchum introduced Mr. Platt Rogers, who addressed the meeting in the interests of The Citizens' Protective League.

Raymond F. Walter, M. Am. Soc. C. E., presented a paper on the "Work of the Reclamation Service," illustrating his remarks with lantern slides.

The question of the National Engineering Congress to be held at the Panama-Pacific Exposition in San Francisco in 1915, was presented by George G. Anderson, M. Am. Soc. C. E., who urged the Association to give the matter its moral and financial support. Having been moved and seconded, the question of financial assistance was referred to the Executive Committee.

Adjourned.

April 12th, 1913.—The meeting was called to order; President Ketchum in the chair; G. N. Houston, Secretary; and present, also, 13 members and 20 guests.

The minutes of the meeting of March 8th, 1913, were read and approved.

A paper, entitled "Structural Steel," by A. F. Reichman, M. Am. Soc. C. E., was presented by the author, and the subject was generally discussed by those present.

A vote of thanks was extended to Mr. Reichman for his paper.

Adjourned.

Atlanta Association

On March 14th, 1912, the Atlanta Association of Members of the American Society of Civil Engineers was organized, with the following officers: Arthur Pew, President; William A. Hansell, Jr., Secretary; and Messrs. James N. Hazlehurst and Alexander Bonnyman, Members of the Executive Committee. The Association will hold its meetings in the house of the University Club.

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms and at all meetings:

American Institute of Mining Engineers, 29 West Thirty-ninth Street, New York City.

American Society of Mechanical Engineers, 29 West Thirty-ninth Street, New York City.

Architekten-Verein zu Berlin, Wilhelmstrasse 92, Berlin W. 66, Germany.

Associação dos Engenheiros Civis Portuguezes, Lisbon, Portugal.

Australasian Institute of Mining Engineers, Melbourne, Victoria, Australia.

Boston Society of Civil Engineers, 715 Tremont Temple, Boston, Mass.

Brooklyn Engineers' Club, 117 Remsen Street, Brooklyn, N. Y.

Canadian Society of Civil Engineers, 413 Dorchester Street, West, Montreal, Que., Canada.

Civil Engineers' Society of St. Paul, St. Paul, Minn.

Cleveland Engineering Society, Chamber of Commerce Building, Cleveland, Ohio.

Cleveland Institute of Engineers, Middlesbrough, England.

Dansk Ingeniorforening, Amaliegade 38, Copenhagen, Denmark.

Engineers' and Architects' Club of Louisville, Ky., 303 Norton Building, Fourth and Jefferson Streets, Louisville, Ky.

Engineers' Club of Baltimore, Baltimore, Md.

Engineers' Club of Minneapolis, 17 South Sixth Street, Minneapolis, Minn.

Engineers' Club of Philadelphia, 1317 Spruce Street, Philadelphia, Pa.

Engineers' Club of St. Louis, 3817 Olive Street, St. Louis, Mo.

Engineers' Club of Toronto, 96 King Street, West, Toronto, Ont., Canada.

Engineers' Society of Northeastern Pennsylvania, 302 Board of Trade Building, Scranton, Pa.

Engineers' Society of Pennsylvania, 219 Market Street, Harrisburg, Pa.

Engineers' Society of Western Pennsylvania, 2511 Oliver Building, Pittsburgh, Pa.

Institute of Marine Engineers, 58 Romford Road, Stratford, London, E., England.

Institution of Engineers of the River Plate, Buenos Aires, Argentine Republic.

Institution of Naval Architects, 5 Adelphi Terrace, London, W. C., England.

Junior Institution of Engineers, 39 Victoria Street, Westminster, S. W., London, England.

Koninklijk Instituut van Ingenieurs, The Hague, The Netherlands.

Louisiana Engineering Society, 321 Hibernia Bank Building, New Orleans, La.

Memphis Engineering Society, Memphis, Tenn.

Midland Institute of Mining, Civil and Mechanical Engineers, Sheffield, England.

Montana Society of Engineers, Butte, Mont.

North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne, England.

Oesterreichischer Ingenieur- und Architekten-Verein, Eschenbachgasse 9, Vienna, Austria.

Pacific Northwest Society of Engineers, 803 Central Building, Seattle, Wash.

Rochester Engineering Society, Rochester, N. Y.

Sachsischer Ingenieur- und Architekten-Verein, Dresden, Germany.

Sociedad Colombiana de Ingenieros, Bogota, Colombia.

Sociedad de Ingenieros del Peru, Lima, Peru.

Societe des Ingenieurs Civils de France, 19 Rue Blanche, Paris, France.

Society of Engineers, 17 Victoria Street, Westminster, S. W., London, England.

Svenska Teknologforeningen, Brunkebergstorg 18, Stockholm, Sweden.

Tekniske Forening, Vestre Boulevard 18–1, Copenhagen, Denmark.

Western Society of Engineers, 1737 Monadnock Block, Chicago, Ill.

ACCESSIONS TO THE LIBRARY

(From April 2d to May 3d, 1913)

DONATIONS*

ASPHALT CONSTRUCTION FOR PAVEMENTS AND HIGHWAYS:

A Pocketbook for Engineers, Contractors, and Inspectors. By Clifford Richardson, M. Am. Soc. C. E. Roan, 7 x 4¼ in., illus., 9 + 155 pp. New York and London, McGraw-Hill Book Company, 1913. $2.00.

This pocket-book has been prepared, the author states, as an aid to highway engineers, contractors, and inspectors, in the details necessary to complete success in the construction of sheet asphalt pavements. The subject-matter is said to be based on the author's personal experience in such work, extending over thirty-five years, and relates in detail to the procedure which must be followed by the contractor and highway engineer, inexperienced in such work, to select the best materials and to organize a force which will produce the best results with such material, in the construction of such pavements. As the book is intended for reference it is published in its present form, in order that it may be easily carried in a coat pocket. The Contents are: Introductory; Broken Stone; Foundation; The Intermediate Course; The Mineral Aggregate; Filler or Dust; Native Bitumens; Fluxes; Asphalt Cement; Surface Mixtures; Maintenance and Repairs; The Plant; Work Upon the Streets; Advice to Engineers, Contractors and Inspectors; Laboratory; Methods for Examination of Bituminous Materials and Mineral Aggregates; Instructions for Taking Samples and Specimens of Materials for Examination; Index.

SPECIFICATIONS FOR STREET ROADWAY PAVEMENTS

With Instructions to Inspectors on Street Paving Work. By S. Whinery, M. Am. Soc. C. E. Second Edition, Revised, Enlarged, and Entirely Reset. Cloth, 9¼ x 6¼ in., illus., 10 + 116 pp. New York and London, McGraw-Hill Book Company, 1913. $1.00.

The first edition of this book was published in 1907, since which time, great advances have been made in the design and construction of street pavements and in specifications for such work. In this new edition, the author, it is stated, has revised and enlarged the original specifications to conform to such advance, especially as to form, scope, and phraseology. He has also added specifications for two comparatively new kinds of roadway pavement and for concrete sidewalk and concrete combined curb and gutter, as well as a second part, Instructions to Inspectors, in which a complete and comprehensive code of instructions for pavement inspectors, is given. The Contents are: Part I, Specifications: Introductory; Specifications: General; Foundations; Sheet Asphalt Pavement; Asphalt Block Pavement; Granite Block Pavement; Brick Pavement; Wood Block Pavement; Bituminous Concrete Pavement; Hydraulic Concrete Pavement; Experimental or Untried Pavements; Concrete Curb and Gutter; Concrete Sidewalks. Part II, Instructions to Inspectors.

CIVIL ENGINEERS' POCKET-BOOK:

A Reference-Book for Engineers, Contractors, and Students, Containing Rules, Data, Methods, Formulas, and Tables. By Albert I. Frye, M. Am. Soc. C. E. Leather, 7 x 4½ in., illus., 42 + 1 611 pp. New York, D. Van Nostrand Company; London, Constable and Company, Ltd., 1913. $5.00. (Donated by the Author.)

The preparation of notes for this volume, which includes rules, data, methods, formulas, and tables for bridges, buildings, water-works, sewers, surveys, etc., was begun, it is stated, several years ago. The arrangement of the subject-matter in numbered Sections is such that all the general data may be found readily from the Table of Contents. At the end of many of the Sections references to valuable data in leading technical publications will be found. Special attention is invited by the author to the vast number of tables, their completeness and arrangement, nearly all of which are stated to have been subjected to test in practical work. The logarithmic tables are stated to comprise both the common and

* Unless otherwise specified, books in this list have been donated by the publishers.

hyperbolic systems, the latter being useful in certain bridge calculations and in steam engineering, and both the logarithmic and trigonometric tables are carried out to five decimal places. The tables of cubes and squares will be found useful, it is said, to the structural detailer, having been calculated by the incremental, additive method which is self-checking. At the end of the book the author has included an extensive Glossary and an Index.

AN APPRECIATION OF TWO GREAT WORKERS IN HYDRAULICS:

Giovanni Battista Venturi, Born 1746, Clemens Herschel, Born 1842. By Walter G. Kent. Cloth, 10 x 7½ in., illus., 34 pp. London, Blades, East & Blades, 1912. (Donated by the Author.)

This book, it is said, is a brief review of the characteristics and work of two great contributors to the theory and practice of hydraulics: Venturi, who by his perseverance, discovered the precise operation and underlying principles of certain hydraulic phenomena, and Herschel, who by his invention of the Venturi meter, applied these principles and opened the way to greater economy and efficiency in the practical work of his profession. The author states that the purpose of the book will be served if those who hear the name of Venturi will thereby be reminded of that of Herschel and give both men the honor that is their due.

INTRODUCTION À LA SCIENCE DE L'INGENIEUR

Aide-Mémoire des Ingenieurs, des Architectes, etc., Partie Theorique. Par J. Claudel. Huitième Edition, Entièrement Refondue, Revue, et Corrigée, par Georgies Davies. Paper, 9 x 5¾ in., illus., 2 vol. Paris, H. Dunod et E. Pinat, 1913. 28 francs.

The success of this work, it is stated, is due largely to the amount and variety of practical matter contained therein. The subject-matter, the character of which remains practically the same as in former editions, has been thoroughly revised and modified to conform to present methods of instruction in technical schools, the old mathematical and mechanical characters having been replaced by modern ones. The chapter on Geometry is stated to be entirely new, as well as the special chapters on Graphical Calculations and Mechanics, some new ideas in regard to the theory of potential and elasticity having been introduced into the latter chapter. The chapters on Algebra and Analytical Geometry have been considerably enlarged and are said to contain all that is necessary to the study of resistance, hydraulics, electricity, etc. The chapter on Topography has also been enlarged and the instructions made to conform to modern practice. The Contents are: Vol. I, Arithmétique; Algébre; Géométrie; Trigonométre; Topographie. Vol. II. Calcul Différentiel et Intégral; Géométrie Analytique; Calcul Graphique et Mécanique; Mécanique; Géométrie Descriptive; Dessin Graphique et Lavis.

McGRAW ELECTRIC RAILWAY MANUAL, 1913:

The Red Book of American Electric Railway Investments. Edited by Frederic Nicholas. Twentieth Annual Number. Cloth, 13 x 10 in., illus., 39 + 342 pp. New York, McGraw Publishing Company, Inc., 1913. $7.50.

The 1913 edition of this book follows, it is stated, the general principles of the previous editions with the necessary modifications. It is said to be a manual of the securities, traffic statistics, earnings, officers, directors, and equipment of street and interurban railways of the United States, Canada, Cuba, and the West Indies. The subject-matter is arranged alphabetically by States and cities, and under each railway is given a brief history of the company, its capital stock, funded debt, the earnings, expenses, and disposition of incomes for three consecutive years, track and equipment, names and addresses of officers, and addresses of general offices, repair shops, etc. Maps showing the main and connecting lines, as well as the location and nature of the properties, of many of the larger companies are included. At the end of the book a list of street and interurban railway associations is given, with the names and addresses of their officers. There is also an Index of ten pages of the railway companies included in the Manual.

PANAMA, PAST AND PRESENT.

By Farnham Bishop. Cloth, 8 x 5¼ in., illus., 16 + 271 pp. New York, The Century Co., 1913. 75 cents.

In the Introduction to this book it is stated to be a popular treatise on the Panama Canal, made up, as stated in the preface, of fighting and machinery. Chapters I to X have to do with the history of Panama from its earliest times, including

many thrilling and interesting details, of how the Americans built the Panama Railroad in the jungle, and how the French Company attempted to dig the Canal. Chapters XI to XVI, are devoted to the Panama of to-day, including descriptions of the sanitary work accomplished by the American officials, the Canal, the employees, their work and play, etc. The author is the son of Joseph Bucklin Bishop, the Secretary of the Isthmian Canal Commission, from whom and many others he has obtained his information. The Chapter headings are: Geographical Introduction: How Columbus Sought for the Strait; How the Spaniards Settled in Darien; How Nuñez de Balboa Found the South Sea; How Pedrarias, the Cruel, Built Old Panama; How Sir Francis Drake Raided the Isthmus; How Morgan, the Buccaneer, Sacked Old Panama; How the English Failed to Take New Panama; How the Americans Built the Panama Railroad; How the French Tried to Dig the Canal; How Panama Became a Republic; How the Isthmus was Made Healthy; How We Are Building the Canal; How We Live on the Isthmus To-Day; How Colonel Goethals Has Made Good; What the Future May Bring Forth; Appendix: Columbus and Limon Bay; Matachin; Panama and the Pan-American Railroad; Spillway, Gatun Dam; The Spanish Main; Piece of Eight; Value of the $40 000 000 French Purchase; Canal Work, May 1, 1912; Canal Statistics; Panama Canal Toll Rates; Index.

THE ENGINEERING INDEX ANNUAL FOR 1912.

Compiled from the Engineering Index Published Monthly in the *Engineering Magazine* During 1912. Twenty-ninth Year. Cloth, 10¼ x 7¼ in., 8 + 510 pp. New York and London, The Engineering Magazine Co., 1913. $2.00.

This volume of The Engineering Index, together with the ten volumes previously published, forms a continuous index to the engineering and technical literature of the past 29 years, up to October, 1912. The arrangement of the subject-matter remains the same as in previous volumes, the articles being first grouped under such engineering divisions as Civil, Electrical, Industrial Economy, Marine and Naval Engineering, Mechanical, Mining and Metallurgy, Railway, and Street and Electric Railways. They are then divided into special recognized divisions of those subjects, and are afterward sorted into closely related sections, the final arrangement under each section being alphabetical. Serial articles, with a few exceptions, are indexed under the first installment. The Index comprises about 250 periodicals, including English, German, French, Spanish, Italian, and Dutch journals. With each entry are given the title, author, a brief descriptive note defining the scope and purport of the article, the number of words it contains, the name and date of the periodical, and, in many cases, the price, the Index being intended as a guide to the information contained in technical periodicals on engineering literature and closely allied subjects. An alphabetical list of periodicals is given, including name, issues per year, and place of publication and there is also a Classification of the Index which gives the main and sub-heads of the arrangement, as well as every catch-word, with page references.

Gifts have also been received from the following:

Am. Electrochemical Soc. 1 vol.
Am. Inst. of Min. Engrs. 1 bound vol.
Am. Ry. Bridge and Bldg. Assoc. 1 vol.
Am. Ry. Eng. Assoc. 3 pam.
Arnold, Bion J. 2 bound vol., 1 pam.
Assoc. Amicale des Anciens Eleves de l'Ecole Centrale des Arts et des Manufactures. 1 vol.
Baltimore, Md.-Harbor Board. 1 pam.
Bengal, India-Irrig. Dept. 1 pam.
Bibbins, James Rowland. 1 bound vol.
Branner, John C. 1 pam.
Brookline, Mass.-Water Board. 1 pam.
Bureau of Ry. Economics. 2 pam.
Burgess, H. 1 vol., 1 pam.
California-Dept. of Eng. 3 vol.
California-R. R. Comm. 1 bound vol.
California-State Conservation Comm. 1 vol.
California-State Min. Bureau. 1 bound vol.
California-State Water Comm. 2 vol.
Canada-Dept. of Mines. 6 pam., 11 maps.
Canada-Dept. of Rys. and Canals. 1 pam.
Canada-Supt. of Forestry. 1 pam.
Canadian Min. Inst. 1 vol.
Chicago San. Dist. 1 bound vol.
Cincinnati Northern R. R. Co. 1 pam.
Clark, Roscoe N. 4 pam.
Cleveland, Ohio-River and Harbor Comm. 1 pam.
Cleveland, Cincinnati, Chicago & St. Louis Ry. Co. 1 pam.
Colorado-Bureau of Mines. 1 bound vol.
Colorado-State Agri. Coll. 1 pam.
Colorado-State R. R. Comm. 1 pam.
Colorado, Univ. of. 1 vol., 1 pam.
Columbia Univ. 1 pam.
Connecticut - Public Utilities Comm. 1 bound vol.
Connecticut-Rivers, Harbors and Bridges Comm. 1 pam.
Delaware-Oyster Survey Comm. 1 pam.
de Varona, I. M. 1 pam.
Dist. of Columbia-Insp. of Bldgs. 1 vol.
Engrs. Club. 1 bound vol.
Engrs'. Soc. of Pennsylvania. 1 vol.
Fairmount Park Art Assoc. 1 pam.
Fitchburg, Mass.-City Engr. 1 pam.
Florida-R. R. Comm. 1 pam.
Ford, Frederick L. 1 pam.
Goodrich, E. P. 2 pam.

Great Britain-Road Board. 2 pam.
Haviland, Dozier & Tibbetts. 1 pam.
Hedde, Peter. 1 bound vol.
Honolulu, Hawaii-San. Comm. 1 pam.
Illinois-Highway Comm. 4 pam.
Illinois-State Canal Commrs. 1 bound vol.
Institution of Civ. Engrs. 1 bound vol.
Iowa-State Library. 1 pam.
Jameson, Charles Davis. 1 pam.
Jurgensen, D. F. 3 pam.
Kansas-Public Utilities Comm. 1 vol.
Kansas-State Board of Agri. 1 bound vol.
Kentucky-Commr. of Public Roads. 3 pam.
Kentucky-R. R. Comm. 1 map.
Koninklijk Instituut van Ingenieurs. 1 pam.
Leominster, Mass.-Water Board. 1 pam.
Lewiston, Me.-Water Board. 1 pam.
Little Falls, N. Y. - Board of Public Works. 1 pam.
Louisiana-Board of Agri. and Immigration. 2 pam., 1 map.
McBean, D. D. 1 pam.
Madras, India-Public Works Dept. 1 pam.
Maine-Registrar of Vital Statistics. 1 bound vol.
Massachusetts-Board of Harbor and Land Commrs. 1 bound vol.
Massachusetts-R. R. Commrs. 1 bound vol.
Massachusetts-Wachusett Mountain State Reservation Comm. 2 pam.
Mexican Ry. Co., Ltd. 2 pam.
Michigan Central R. R. Co. 1 pam.
Miller, Cyrus C. 1 pam.
Minneapolis & St. Louis R. R. Co. 1 pam.
Missouri, Univ. of. 3 pam.
National Fire Protection Assoc. 1 pam.
Nebraska, Univ. of. 1 pam.
Nevada-State Engr. 3 pam.
New Jersey-Board of Equalization of Taxes. 1 pam.
New Jersey-Commr. of Public Roads. 1 bound vol.
New York City-Dept. of Docks and Ferries. 2 pam.
New York City-Dept. of Parks. 2 pam.
New York City-Met. Sewerage Comm. 2 pam.
New York State-Public Service Comm., First Dist. 1 bound vol.
New York-State Reservation at Saratoga Springs. 1 pam.
New York, Chicago & St. Louis R. R. Co. 1 pam.
Newburgh, N. Y. - Board of Water Commrs. 1 pam.
North Carolina-Geol. and Economic Survey. 2 pam.
Ohio-Geol. Survey. 1 bound vol.
Ohio-Highway Dept. 1 pam.
Ohio-State Board of Health. 1 bound vol.
Ohio Elec. Light Assoc. 1 pam.
Oregon-State Engr. 2 pam.
Oregon-State Library. 1 pam.
Pennsylvania R. R. Co. 1 pam.
Pennsylvania State Coll. 1 vol.
Peoria & Eastern Ry. Co. 1 pam.
Permanent Inter. Assoc. of Cong. of Navigation. 10 pam.
Pulligny, Jean de. 1 pam.
Punjab, India-Public Works Dept. 1 pam.
Reibling, W. C. 1 pam.
Rhode Island-Shell Fisheries Comm. 1 pam.
Rutland, Vt.-City Clerk. 1 pam.
Rutland R. R. Co. 1 pam.
Saginaw, Mich.-Board of Water Commrs. 1 pam.
St. Louis, Mo., Merchants' Exchange. 1 vol.
Smithsonian Institution. 4 pam.
Société des Ingénieurs Civils de France. 1 vol.
Soc. for the Promotion of Eng. Education. 1 bound vol.
Soc. of Chemical Industry. 1 pam.
South African Eng. Standards Committee. 3 pam.
South Dakota-R. R. Commrs. 1 bound vol.
Springfield, Mass.-Water Commrs. 1 vol.
Syracuse Univ. 1 vol.
Taunton, Mass.-Water Commrs. 1 pam.
Tonindustrie-Zeitung. 2 pam.
Toronto, Hamilton & Buffalo Ry. Co. 1 pam.
Toronto, Univ. of. 1 vol.
Union Pacific R. R. Co.-Educational Bureau. 1 pam.
U. S.-Bureau of Mfrs. 1 bound vol., 1 pam.
U. S.-Bureau of Mines. 6 pam.
U. S.-Bureau of Standards. 3 pam.
U. S.-Bureau of Statistics. 1 pam.
U. S.-Census Bureau. 2 bound vol., 1 pam.
U. S.-Chf. of Engrs. 26 specif.
U. S.-Coast and Geodetic Survey. 2 bound vol., 4 pam.
U. S.-Corps of Engrs. 1 pam.
U. S.-Forest Service. 32 pam.
U. S.-Geol. Survey. 2 bound vol., 7 vol., 5 pam., 61 maps.
U. S.-Interstate Commerce Comm. 1 vol.
U. S.-Navy Dept. 1 vol.
U. S.-Office of Public Roads. 1 pam.
U. S.-Weather Bureau. 3 bound vol., 7 pam.
Vermont, Univ. of. 1 vol.
Washington-State Board of Tax Commrs. 1 pam.
West Virginia-Geol. Survey. 4 bound vol.

BY PURCHASE

Reports of Decisions of the Public Service Commission, First District, of the State of New York; Vol. 2, Sept. 1st, 1909, to January 1st, 1912. Published by the Commission, New York, 1912.

Industrial Chemistry: A Manual for the Student and Manufacturer. Edited by Allen Rogers and Alfred B. Aubert. D. Van Nostrand Company, New York, 1913.

Winding Engines and Winding Appliances, Their Design and Economical Working. By George McCulloch and T. Campbell Futers. Edward Arnold, London, 1912.

The Elements of Machine Design, Pt. 2 : Chiefly on Engine Details. By W. Cawthorne Unwin and A. L. Mellanby. New and Revised Edition. Longmans, Green and Co., New York and London, 1912.

A Handbook of Land Drainage, Principally Based Upon the Requirements of the Syllabus Issued by the Surveyors' Institution. By G. S. Mitchell. Third Edition. Land Agents' Record, Limited, London.

Mitteilungen über Forschungsarbeiten auf dem Gebiete des Ingenieurwesens, insbesondere aus den Laboratorien der technischen Hochschulen. Herausgegeben vom Verein deutscher Ingenieure. Hefte 131-132. Julius Springer, Berlin, 1913.

The Elements of Heating and Ventilation: A Text-Book for Students, Engineers and Architects. By Arthur M. Greene, Jr. John Wiley & Sons, New York: Chapman & Hall, Limited, London, 1913.

The Gas, Petrol, and Oil Engine, Vol. 2: The Gas, Petrol and Oil Engine in Practice. By Dugald Clerk and G. A. Burls. New and Revised Edition. John Wiley & Sons, New York, 1913.

The Theory and Practice of Working Plans (Forest Organization). By A. B. Recknagel. John Wiley & Sons, New York: Chapman & Hall, Limited, London, 1913.

American Mine Accounting: Methods and Forms Employed by Leading Mining Companies. By W. H. Charlton. McGraw-Hill Book Co., New York and London, 1913.

Electric Furnaces in the Iron and Steel Industry. By W. Rodenhauser and I. Schoenawa. From Advance Sheets of the Second German Edition. Authorized Translation and Additions by C. H. Vom Baur. John Wiley & Sons, New York ; Chapman & Hall, Limited, London, 1913.

Design of Polyphase Generators and Motors. By Henry M. Hobart. McGraw-Hill Book Co., New York and London, 1913.

Synchronous Motors and Converters: Theory and Methods of Calculation and Testing. By André E. Blondel. Translated from the French by C. O. Mailloux, with Additional Chapters by Comfort A. Adams. McGraw-Hill Book Co., New York and London, 1913.

Worm Gearing. By Hugh Kerr Thomas. McGraw-Hill Book Co., New York and London, 1913.

Evolution of the Internal Combustion Engine. By Edward Butler. Charles Griffin & Company, Limited, London, 1912.

Analytical Chemistry, Vol. 2 : Quantitative Analysis. By F. P. Treadwell. Authorized Translation from the German, by William T. Hall. Third Edition, Revised and Enlarged. John Wiley & Sons, New York ; Chapman & Hall, Limited, London, 1912.

Determinative Mineralogy with Tables for the Determination of Minerals by Means of Their Chemical and Physical Characters. By J. Volney Lewis. John Wiley & Sons, New York; Chapman & Hall, Limited, London, 1913.

Manual of Wireless Telegraphy and Telephony. By A. Frederick Collins. Third Edition, Revised and Enlarged. John Wiley & Sons, New York; Chapman & Hall, Limited, London, 1913.

A Manual of Cement Testing for the Use of Engineers and Chemists in Colleges and in the Field. By William Allyn Richards and Henry Briggs North. D. Van Nostrand Company, New York, 1912.

Transmission Line Formulas for Electrical Engineers and Engineering Students. By Herbert Bristol Dwight. D. Van Nostrand Company, New York, 1913.

An Introduction to the Study of Fuel: A Text Book for Those Entering the Engineering, Chemical and Technical Industries. By F. J. Brislee. D. Van Nostrand Company, New York, 1912.

Boundaries and Landmarks: A Practical Manual. By A. C. Mulford. D. Van Nostrand Company, New York, 1912.

Statische Berechnung von Tunnelmauerwerk: Grundlagen und Anwendung auf die wichtigsten Belastungsfälle. Von Otto Kommerell. Wilhelm Ernst & Sohn, Berlin, 1912.

Taschenbuch für Kanalisations=Ingenieure. Von K. Imhoff. Zweite Auflage. R. Oldenbourg, München und Berlin, 1912.

SUMMARY OF ACCESSIONS

(From April 2d to May 3d, 1913)

Donations (including 21 duplicates)	366
By purchase	25
Total	391

MEMBERSHIP

ADDITIONS

(From April 4th to May 8th, 1913)

MEMBERS		Date of Membership.
BOUILLON, ALFRED VICTOR. Civ. and Mech. Engr. (H. K. Owens-A. V. Bouillon), Empire Bldg., Seattle, Wash.		April 2, 1913
BURT, LUTHER HAROLD. (L. W. Burt & Son), 39 Pearl St., Hartford, Conn.	Assoc. M. M.	Nov. 1, 1910 April 2, 1913
BUTLER, JOHN SOULE. U. S. Asst. Engr., U. S. Engr. Office, Nashville, Tenn.	Assoc. M. M.	Mar. 4, 1908 April 2, 1913
CAMERON, HARRY FRANK. Div. Engr., Bureau of Public Works, Manila, Philippine Islands	Assoc. M. M.	Oct. 2, 1907 Feb. 4, 1913
DUSENBURY, ALLAN THEODORE. Vice-Pres. and Chf. Engr., Louisiana Meadows Co., 901 Maison Blanche Bldg., New Orleans, La.		April 2, 1913
ELLMS, JOSEPH WILTON. Cons. Engr. (Pollard & Ellms), 603 Miles Greenwood Bldg., Cincinnati, Ohio		April 2, 1913
EVANS, JOSEPH DEAN. Constr. Mgr., Elec. Bond & Share Co., 71 Broadway, New York City (Res., Alta Ave., Park Hill, Yonkers, N. Y.)		April 2, 1913
GRAVES, EDWARD MICHAEL. Pres., Central Dredging Co., 542 Rockefeller Bldg., Cleveland, Ohio	Assoc. M.	Mar. 2, 1909 April 2, 1913
GRAY, ALEXANDER. Asst. Engr.-in-Chg., Upper Ottawa Storage, Dept. of Public Works, Canada, Box 560, Ottawa, Ont., Canada		April 2, 1913
GRETH, JOHN CHARLES WILLIAM. Mgr., Water Purifying Dept., William B. Scaife & Sons Co., 221 First Ave., Pittsburgh, Pa.		Mar. 4, 1913
HARRIS, GUY WALTER. Chf. Engr., A., T. & S. F. Ry., 1005 Kerckhoff Bldg., Los Angeles, Cal.	Assoc. M. M.	June 5, 1907 Mar. 4, 1913
HARVEY, HERBRAND. Care, S. Pearson & Son, Inc., 507 Fifth Ave., New York City		April 2, 1913
HAYNES, GEORGE ALBERT. Engr., The Modern Steel Structural Co., 207 McCall St., Waukesha, Wis.	Assoc. M. M.	Sept. 2, 1908 April 2, 1913
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RESIGNATION

MEMBERS	Date of Resignation.
LILLY, GEORGE WASHINGTON	April 2, 1913

DEATHS

ELDRIDGE, GRIFFITH MORGAN. Elected Associate Member, June 1st, 1892, Member September 3d, 1902; died August 30th, 1912.

REED, WILLIAM BELDEN, JR. Elected Junior, December 1st, 1896, Associate Member, June 5th, 1907; died April 3d, 1913.

VEHRENKAMP, HENRY WILLIAM. Elected Associate Member, June 5th, 1907, Member, June 30th, 1911; died April 25th, 1913.

Total Membership of the Society, May 8th, 1913, 6 919.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST

(April 2d to May 3d, 1913)

NOTE.—*This list is published for the purpose of placing before the members of this Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS

In the subjoined list of articles, references are given by the number prefixed to each journal in this list:

(1) *Journal*, Assoc. Eng. Soc., Boston, Mass., 30c.
(2) *Proceedings*, Engrs. Club of Phila., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Chicago, Ill., 50c.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Gesundheits Ingenieur*, München, Germany.
(8) *Stevens Institute Indicator*, Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *Engineering Record*, New York City, 10c.
(15) *Railway Age Gazette*, New York City, 15c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Electric Railway Journal*, New York City, 10c.
(18) *Railway and Engineering Review*, Chicago, Ill., 15c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 20c.
(21) *Railway Engineer*, London, England, 1s, 2d.
(22) *Iron and Coal Trades Review*, London, England, 6d.
(23) *Railway Gazette*, London, England, 6d.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England, 4d.
(27) *Electrical World*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal*, Royal Society of Arts, London, England, 6d.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium, 4 fr.
(31) *Annales* de l'Assoc. des Ing. Sortis des Ecoles Spéciales de Gand, Brussels, Belgium, 4 fr.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France, 1 fr.
(34) *Portefeuille Economiques des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(36) *Cornell Civil Engineer*, Ithaca, N. Y.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(39) *Technisches Gemeindeblatt*, Berlin, Germany, 0, 70m.
(40) *Zentralblatt der Bauverwaltung*, Berlin, Germany, 60 pfg.
(41) *Elektrotechnische Zeitschrift*, Berlin, Germany.
(42) *Proceedings*, Am. Inst. Elec. Engrs., New York City, $1.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governors Island, New York Harbor, 50c.
(45) *Colliery Engineer*, Scranton, Pa. 25c.
(46) *Scientific American*, New York City, 15c.
(47) *Mechanical Engineer*, Manchester, England, 3d.
(48) *Zeitschrift*, Verein Deutscher Ingenieure, Berlin, Germany, 1, 60m.
(49) *Zeitschrift für Bauwesen*, Berlin, Germany.
(50) *Stahl und Eisen*, Düsseldorf, Germany.
(51) *Deutsche Bauzeitung*, Berlin, Germany.
(52) *Rigasche Industrie-Zeitung*, Riga, Russia, 25 kop.
(53) *Zeitschrift*, Oesterreichischer Ingenieur und Architekten Verein, Vienna, Austria, 70h.
(54) *Transactions*, Am. Soc. C. E., New York City, $12.

(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $6.
(57) *Colliery Guardian*, London, England, 5d.
(58) *Proceedings*, Engrs.' Soc. W. Pa., 803 Fulton Bldg., Pittsburgh, Pa., 50c.
(59) *Proceedings*, American Water-Works Assoc., Troy, N. Y.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *Industrial World*, 59 Ninth St., Pittsburgh, Pa., 10c.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 5c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 6d.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England, 6d.
(69) *Der Eisenbau*, Leipzig, Germany.
(71) *Journal*, Iron and Steel Inst., London, England.
(71*a*) *Carnegie Scholarship Memoirs*, Iron and Steel Inst., London, England.
(72) *American Machinist*, New York City, 15c.
(73) *Electrician*, London, England, 18c.
(74) *Transactions*, Inst. of Min. and Metal., London, England.
(75) *Proceedings*, Inst. of Mech. Engrs., London, England.
(76) *Brick*, Chicago, Ill., 10c.
(77) *Journal*, Inst. Elec. Engrs., London, England, 5s.
(78) *Beton und Eisen*, Vienna, Austria, 1, 50m.
(79) *Forscherarbeiten*, Vienna, Austria.
(80) *Tonindustrie Zeitung*, Berlin, Germany.
(81) *Zeitschrift für Architektur und Ingenieurwesen*, Wiesbaden, Germany.
(82) *Mining and Engineering World*, Chicago, Ill., 10c.
(83) *Gas Age*, New York City, 15c.
(84) *Le Ciment*, Paris, France.
(85) *Proceedings*, Am. Ry. Eng. Assoc., Chicago, Ill.
(86) *Engineering-Contracting*, Chicago, Ill., 10c.
(87) *Railway Engineering and Maintenance of Way*, Chicago, Ill., 10c.
(88) *Bulletin* of the International Ry. Congress Assoc., Brussels, Belgium.
(89) *Proceedings*, Am. Soc. for Testing Materials, Philadelphia, Pa., $5.
(90) *Transactions*, Inst. of Naval Archts., London, England.
(91) *Transactions*, Soc. Naval Archts. and Marine Engrs., New York City.
(92) *Bulletin*, Soc. d'Encouragement pour l'Industrie Nationale, Paris, France.
(93) *Revue de Métallurgie*, Paris, France, 4 fr. 50.
(94) *The Boiler Maker*, New York City, 10c.
(95) *International Marine Engineering*, New York City, 20c.
(96) *Canadian Engineer*, Toronto, Ont., Canada, 10c.
(98) *Journal*, Engrs. Soc. Pa., Harrisburg, Pa., 30c.
(99) *Proceedings*, Am. Soc. of Municipal Improvements, New York City, $2.
(100) *Professional Memoirs*, Corps of Engrs., U. S. A., Washington, D. C., 50c.
(101) *Metal Worker*, New York City, 10c.
(102) *Organ für die Fortschritte des Eisenbahnwesens*, Wiesbaden, Germany.
(103) *Mining and Scientific Press*, San Francisco, Cal., 10c.
(104) *The Surveyor and Municipal and County Engineer*, London, England, 6d.
(105) *Metallurgical and Chemical Engineering*, New York City, 25c.
(106) *Transactions*, Inst. of Min. Engrs., London, England, 6s.
(107) *Schweizerische Bauzeitung*, Zürich, Switzerland.
(108) *Southern Machinery*, Atlanta, Ga., 10c.

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Results of Recent Flood at Columbus, Damages to Bridges and Levees and Plans for Improving River Channels.* J. J. Morgan. (14) Apr. 19.
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Some Features of Highway Bridge Practice Without Engineering Supervision.* F. R. White and J. H. Ames. (86) Apr. 30.
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Die Begrenzung der Betonzugspannungen, ein Beitrag zur Erzielung einheitlicher Vorschriften für Eisenbetonbauten.* K. W. Schaechterle. (78) Serial beginning Apr. 1.
Der Ems-Weser-Kanal und seine Eisenbetonbauten.* Hart. (78) Apr. 1; (51) Sup. No. 8.
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Electrical.

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A Single-Phase Alternate-Current Contactor.* E. Wilson and others. (73) Mar. 28.
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Ueber das Anlassen von Kaskadenumformern.* R. Johs. Jensen. (41) Apr. 3.
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Gas Power for Ship Propulsion.* A. C. Holzapfel. (90) Vol. 54.
The Effect of Bilge Keels on the Rolling of Lightships.* George Idle and G. S. Baker. (90) Vol. 54.
Results of Calculations Regarding the Effect of an Internal Free Fluid Upon the Initial Stability and the Stability at Large Angles in Ships of Various Forms.* A. Cannon. (90) Vol. 54.
The Solignac-Grille Boiler and Its Application in French Channel Steamers.* G. Hart. (90) Vol. 54.
Description of a Tide Indicator.* G. J. Baugh. (90) Vol. 54.
The Arrangement of Boat Installations on Modern Ships.* Axel Welin. (90) Vol. 54.
Torsional Vibrations of Elastic Shafts of Any Cross Section and Mass Distribution and Their Application to the Vibration of Ships.* L. Gümbel. (90) Vol. 54.
Load-Extension Diagrams Obtained Photographically with an Automatic Self-Contained Optical Load-Extension Indicator.* W. E. Dalby. (90) Vol. 54.
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Present Use of the Septic Tank. Henry N. Ogden. (99) 1910.
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Notes on the Design and Construction of the Sewage Disposal System of Toronto.* C. H. Rust. (99) 1910.
European Sewage Disposal Works.* Rudolph Hering. (99) 1910.
Report of the Committee, Am. Soc. of Mun. Improvements, on Street Cleaning and Garbage Disposal. Louis L. Tribus. (99) 1910.
District Steam Heating Plants.* Paul Mueller. (99) 1910.
Report of Sub-Committees, Am. Soc. of Mun. Improvements, on Standard Sewer Specifications. E. J. Fort. (99) 1911.
Schedule of Analytical Data for Sewer Pipe, Demands and Properties; Mill, Field and Laboratory Tests. (99) 1911.
The Sanitation of Swimming Pools. John W. M. Bunker and Melville C. Whipple. (99) 1911.
Chicago Sewage Disposal Experiment Station.* Langdon Pearse. (99) 1911.
Report of Committee, Am. Soc. of Mun. Improvements, on Garbage Disposal and Street Cleaning. Louis L. Tribus. (99) 1911.
Storm Water Discharge. R. O. Wynne-Roberts and T. Brockmann. (104) Serial beginning Mar. 28.
The Collection and Disposal of Municipal Waste. G. H. Herrold. (Paper read before the Civil Engrs.' Soc. of St. Paul.) (1) Apr.
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Les Eboulements de la Tranchée Centrale du Canal de Panama.* A. Dumas. (33) Mar. 22.
Die Berechnung vollkommener Ueberfallwehre. Th. Rehbock. (81) Pt. 2.
Rechnerische Ermittelung des günstigsten parabelförmigen Flussquerschnittes.* Otto Lacmann. (81) Pt. 2.
Uferbestigung aus Eisenbeton, Bauweise *De Muralt.** (80) Jan. 28.
Wehre und Schleusen in der oberen schiffbaren Spree.* Papke. (40) Feb. 22.
Die veränderliche Bewegung des Wassers in Flüssen und Kanälen.* C. Ruprecht. (40) Apr. 16.

*Illustrated.

Vol. XXXIX. MAY, 1913. No. 5.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

This Society is not responsible for any statement made or opinion expressed in its publications.

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AMERICAN SOCIETY OF CIVIL ENGINEERS
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THE ELEVATION OF THE TRACKS OF THE PHILADELPHIA GERMANTOWN AND NORRISTOWN RAILROAD, PHILADELPHIA, PA.

By Samuel Tobias Wagner, M. Am. Soc. C. E.

To be Presented June 4th, 1913.

It is the purpose of this paper to present the more interesting features of the work of abolishing grade crossings on the line of the Philadelphia, Germantown, and Norristown Railroad, a leased line of the Philadelphia and Reading Railway, in the City of Philadelphia, between Green Street and the Richmond Branch Crossing near Wayne Junction.

The Philadelphia and Reading Railway enters the heart of the City of Philadelphia, to the Reading Terminal at Twelfth and Market Streets, by two principal routes:

First.—From the main line on the Schuylkill River through the Subway on Pennsylvania Avenue.

Second.—From Wayne Junction *via* private right of way and Ninth Street.

The avoidance of grade crossings on the first line has been described in the *Transactions*.* It is the purpose of this paper to describe the second, which has recently been completed.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

* *Transactions*, Am. Soc. C. E., Vol. XLIV, p. 1; and Vol. XLVIII, p. 470.

work was introduced into Councils and, after discussion in that body, was finally agreed to by both interests, passed by Councils on October 4th, 1906, and approved by the Mayor on October 13th, 1906. This ordinance also included the abolishment of certain grade crossings on the Richmond Branch of the same railway between Somerset and Richmond Streets, which work will not be described here.

On March 28th, 1907, the agreement authorized by Councils was formally signed by the proper officials of the City and the Railway Company. This agreement, among other things, provided, as follows:

1st. The legal authority for the City to revise the city plans, on account of the changes of grade of the streets, etc.

2d. Authorization of the city officials to prepare plans, specifications, and contracts for the changes of grade of the street, and the opening of new streets, said plans and contracts to be approved by the Railway Company.

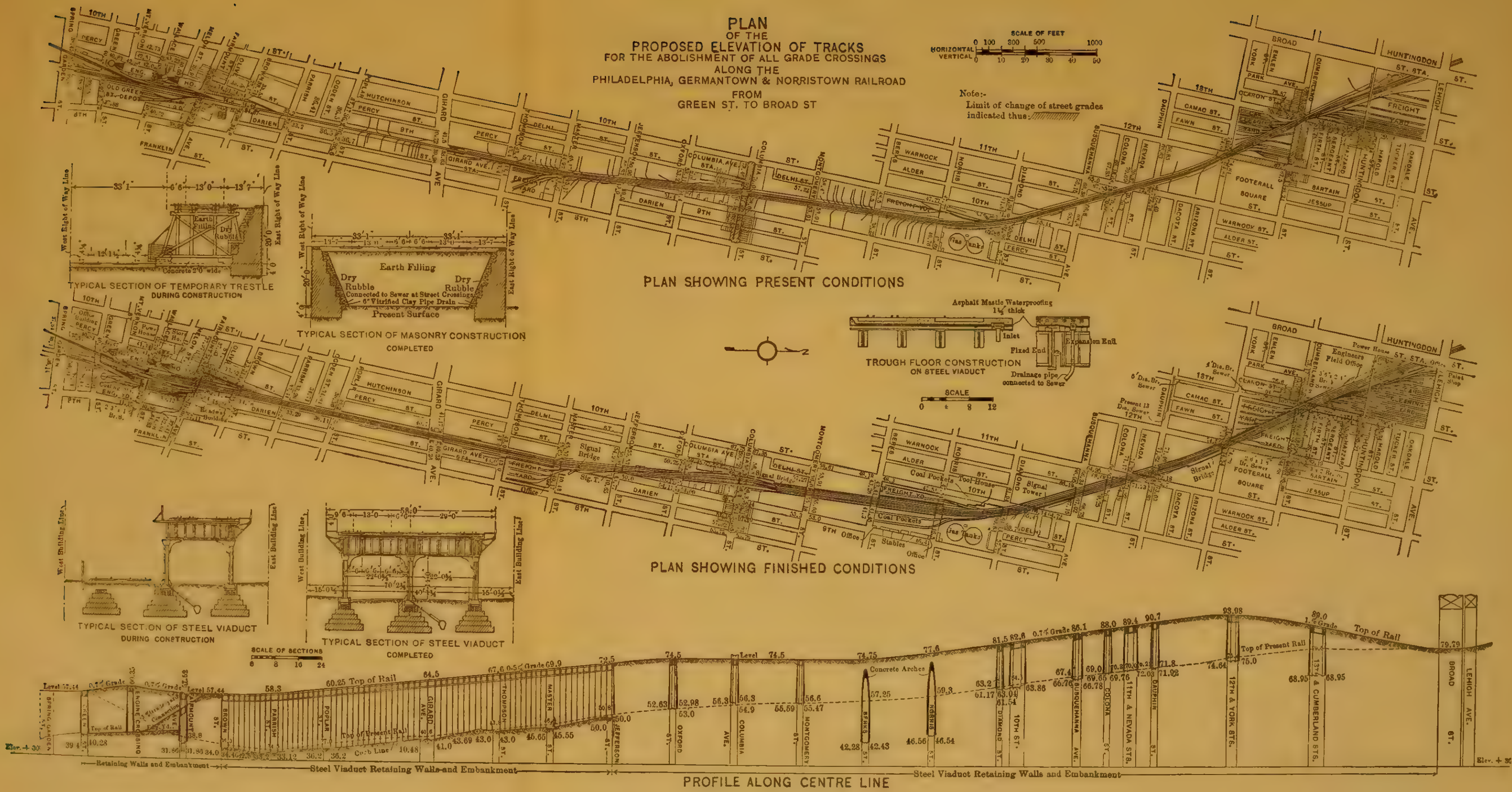
3d. Authorization of the Railway Company to prepare plans and contracts for the work of raising its tracks, with the bridges and all other appurtenances, said plans and contracts to be approved by the City.

4th. Authorization of both the City and the Railway Company to employ engineers and inspectors; also to provide for emergency work in the maintenance of railroad and highway travel, not covered by contract, by force account on the part of the Railway Company and the City.

5th. Division of the cost equally between the Railway and the City as long as the Railway Company does not increase its facilities over and above what it had at the time of passage of the ordinance; all other additional expenses incurred by the Railway Company to be at its sole expense. The cost of the work to be equally divided includes all consequential damages caused by the change of street grades.

6th. For the proper disposal (and proper credit to both parties) of all old material or real estate purchased and not used.

7th. That the representatives of the City and the Railway Company shall be, respectively, the Director of the Department of Public Works and the Chief Engineer.


PLAN
OF THE
PROPOSED ELEVATION OF TRACKS
FOR THE ABOLISHMENT OF ALL GRADE CROSSINGS
ALONG THE
PHILADELPHIA, GERMANTOWN & NORRISTOWN RAILROAD
FROM
GREEN ST. TO BROAD ST
SCALE OF FEET
HORIZONTAL
VERTICAL
Note:-
Limit of change of street grades
indicated thus:
PLAN SHOWING PRESENT CONDITIONS
TYPICAL SECTION OF TEMPORARY TRESTLE
DURING CONSTRUCTION
TYPICAL SECTION OF MASONRY CONSTRUCTION
COMPLETED
Earth Filling
Dry Rubble
Connected to Sewer at Street Crossings
6" Vitrified Clay Pipe Drain
Present Surface
Asphalt Mastic Waterproofing
TROUGH FLOOR CONSTRUCTION
ON STEEL VIADUCT
Fixed End
Expansion End
Drainage pipe connected to Sewer
SCALE
PLAN SHOWING FINISHED CONDITIONS
TYPICAL SECTION OF STEEL VIADUCT
DURING CONSTRUCTION
TYPICAL SECTION OF STEEL VIADUCT
COMPLETED
SCALE OF SECTIONS
Top of Rail
Top of Present Rail
Concrete Arches
Retaining Walls and Embankment
Steel Viaduct Retaining Walls and Embankment
PROFILE ALONG CENTRE LINE

General Description.

The following is a general description of the work: Beginning at Green Street, to which point from the south the tracks had already been elevated, they run level at an elevation of 57.44 to a point near Brown Street. A slight hump is placed in this profile to cross the engine passageway in the Green Street Yard. As far as Brown Street, the four main tracks are carried on fill between concrete retaining walls with steel plate-girder bridges crossing the engine passageway and Fairmount Avenue at four different levels. At Fairmount Avenue the grade of the street was lowered so as to allow 14 ft. beneath the bridges leading to the engine yard on the east and west sides of the main tracks. A new locomotive coaling station, with a storage capacity of 2 000 tons, is located in the east yard.

At Brown Street the tracks are over the bed of Ninth Street and are carried on a four-track, steel viaduct with plate-girder spans, generally 50 ft. long, supported by transverse girders and three lines of columns, and, in turn, supporting a solid steel floor, which is waterproofed. This viaduct is on a grade of 0.5%, and is on a tangent as far as Master Street. At Girard Avenue a new elevated station is supported over the street.

Between Thompson and Master Streets, and Eighth and Ninth Streets, the old freight yard is raised to the new level with a ramp approach from Eighth and Master Streets.

At Jefferson Street the tracks are supported on earth fill with third-class, masonry retaining walls and concrete abutments, and this type of construction continues to the end of the line at the Richmond Branch Crossing. At Jefferson Street the line leaves Ninth Street and occupies its own right of way. This right of way, 66 ft. in width, formerly extended as far south as Girard Avenue, but, under the ordinance authorizing the work, it was released to the City for street purposes beneath the viaduct.

The 0.5% grade extends about to Oxford Street, where the tracks are level at an elevation of 74.5, to a point near Montgomery Street.

Between Oxford Street and Columbia Avenue is the Columbia Avenue Station, having island platforms with stairways leading to the main waiting- and baggage-rooms at the southwest corner of Ninth Street and Columbia Avenue.

The tracks cross Berks and Norris Streets on concrete arches, replacing old iron plate-girder bridges which formerly carried the low-level tracks over these streets.

Between Berks and Norris Streets on the west side is a freight yard raised nearly to the new level, with a ramp approach parallel to Tenth Street, and on the east side, on property of the Railway Company, there are two large commercial coal yards. At the northeast corner of Tenth and Norris Streets there is a smaller coal yard.

Between Berks and Norris Streets the tracks ascend on a 0.7% grade to the summit at York Street and then descend on a 1% grade to Broad Street, where the old level is reached.

Between Norris and Cumberland Streets there are five tracks crossing a large number of streets, at very acute angles, on steel bridges of plate-girder type with solid water-proofed floors. Between York and Cumberland Streets there are two elevated freight yards, and north of Cumberland Street there is a car-cleaning yard on the east side.

Between Broad Street and a point near Seventeenth and Indiana Streets no work was required, as there were no grade crossings in this territory.

From Seventeenth and Indiana Streets to Tioga Street, the grade is 1.06%, and there are five tracks as far as Westmoreland Street and four north of that point. In order to obtain the 1.06% grade, it was necessary to raise a truss bridge of the Philadelphia, Germantown, and Chestnut Hill Railroad (Pennsylvania System) about 4 ft. This was done at a cost of $18 384.47.

The new elevation required changes in the grades of Allegheny Avenue, Westmoreland Street, Ontario Street, and Hunting Park Avenue, and slight changes at Atlantic and Venango Streets. The changes at Allegheny Avenue and Westmoreland and Ontario Streets necessitated those in a number of other streets shown on the general plans, Plates LIV and LV.

New stations were constructed at Tioga and Nicetown, and a coal yard of the Railway Company was reconstructed at Hunting Park Avenue.

Preparation of Plans and Contracts.

Plans and specifications for the various contracts were duly prepared for the work by the Railway Company and the City, and were

PLATE LV.
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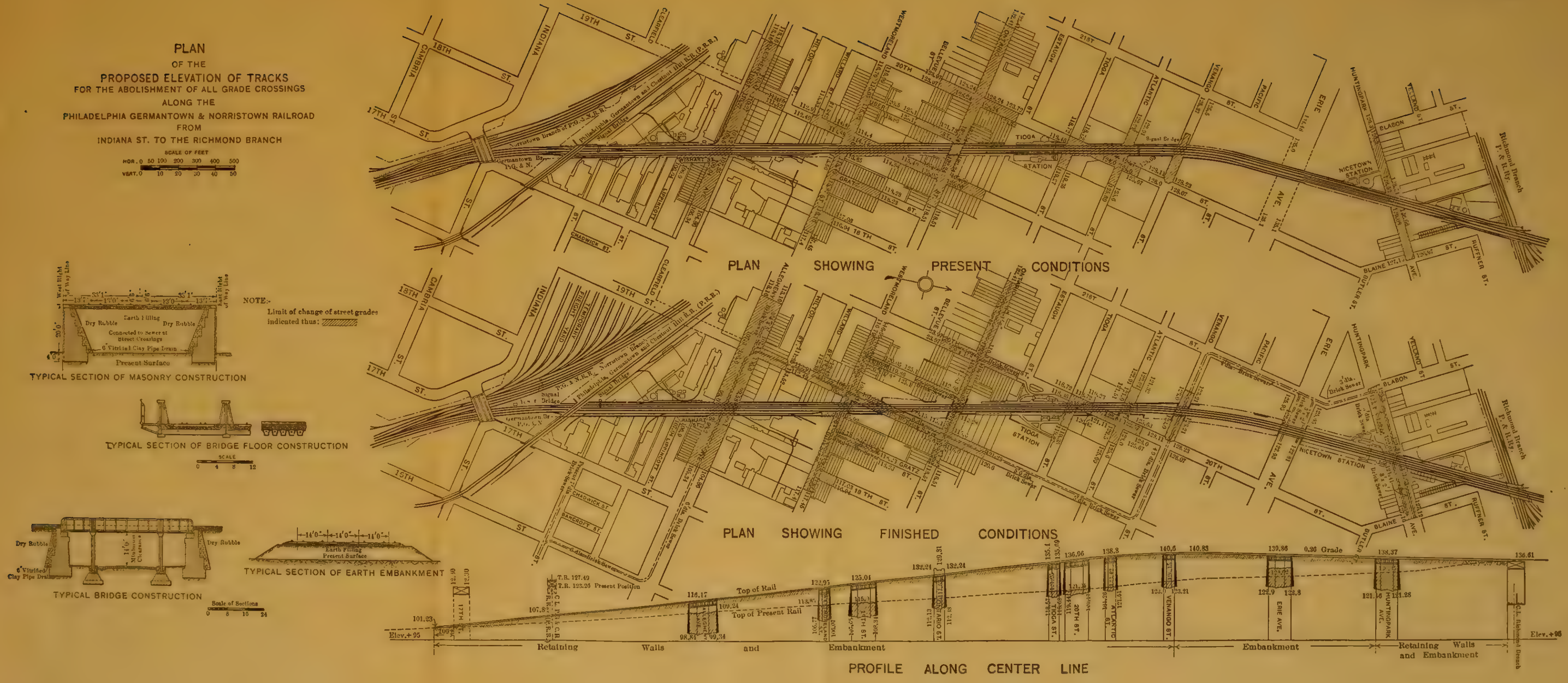
MAY, 1913.
WAGNER ON
TRACK ELEVATION, PHILADELPHIA PA.



submitted for approval to the other interest before asking for bids. All work was advertised publicly, and awards were made to the lowest bidder.

Division Into Contracts.

In the summer of 1906, it was decided to divide the work into contracts so that it could be attacked from the greatest number of points at one time, and so that, as far as possible, the work requiring special skill could be separated in order to reduce the number of contracts to a minimum. All track work was done by Railway Company's forces on what were known as emergency orders.

Tables 1 and 2 show the contracts into which the work was divided. All numbers from 1 to 100 were executed by the Railway Company; those above 100 by the City.

Emergency Orders.

The ordinance provided that in case of emergency work in maintaining railroad or highway travel, and in other cases where necessary—not covered by contract—either the Railway Company or the City should have authority to employ laborers, hire machinery, and purchase materials to perform such work. Such work, when jointly agreed upon, constituted what was known as an emergency order. On the part of the Railway Company, these orders generally applied to the construction of temporary and permanent tracks, the work being done by the Operating Department; and on the part of the City to work connected with the maintenance of underground municipal structures. They were also used for keeping account of numerous minor additional betterment items desired by the Railway Company during the progress of the work, and paid for entirely by them. All labor on pay rolls was carefully checked, and all prices of materials were approved prior to purchase.

Temporary Yards.

Besides the heavy passenger business conducted over the line which was to be elevated, involving about 467 train movements in 24 hours, the Railway Company operated freight yards at Eighth and Master, Tenth and Berks, and Thirteenth and Huntingdon Streets, and a locomotive coaling station and engine repair yard at Ninth and Green Streets.

TABLE 1.—LIST OF CONTRACTS WITH RAILWAY COMPANY.

No.	Description.	Contractor.	Date of contract.	Date of final estimate.	Amount.
1	Masonry and embankment, Green to Brown	James McGraw Co.	6- 4-09	8-31-12	$291 561.46
2*	Foundations for steel viaduct	Owen J. Evers	6-14-09	8-31-09	6 383.38
2R	Foundations for steel viaduct	James McGraw Co.	11- 6-09	9-30-10	179 538.56
3	Bridges and viaduct, Green to Jefferson	McClintic-Marshall Cons. Co	6-15-09	12-30-11	842 741.57
4	Masonry and embankment, Jefferson to Montgomery	Armstrong & Latta Co.	7-31-09	9-30-11	171 304.96
5	Masonry and embankment, Montgomery to Susquehanna	Armstrong & Latta Co.	1-27-08	11- 6-09	460 993.79
6	Bridges, Oxford, Columbia Ave., Montgomery	S. F. Shoemaker & Co.	7-30-09	1-31-12	96 300.66
7	Masonry and embankment, Susquehanna to Broad	James McGraw Co.	1-21-08	9-30-09	290 580.77
8	Bridges, Berks to Broad	McClintic-Marshall Cons. Co	2-15-08	8-31-10	340 794.53
9	Masonry and embankment, Indiana to Tioga	Armstrong & Latta Cons. Co.	8- 2-09	6-30-11	106 812.17
10	Masonry and embankment, Tioga to Richmond Branch	Enos L. Seeds	8-18-09	6-30-11	111 275.19
11	Bridges, Indiana to Richmond Branch	American Bridge Co.	8-17-09	11-29-11	267 559.51
12†	Masonry, etc., Master St. Yard	Owen J. Evers	6-14-09	8-31-09	16 667.12
12R	Masonry, etc., Master St. Yard	James McGraw Co.	11- 6-09	10-31-11	89 397.59
14	Masonry, etc., York St. Yards	Armstrong & Latta Co.	1-17-08	10-31-11	67 059.23
15	Columbia Ave. Station	Irwin & Leighton	4-21-10	11-30-12	217 134.15
16	Tioga Station	Enos L. Seeds	1-20-10	9-30-12	62 886.64
17	Nicetown Station	Fred. A. Havens & Co.	1-22-10	12-30-11	43 554.57
19	Signals, Green to Broad	Union Switch & Signal Co.	7- 2-09	1-31-12	127 462.90
21	Locomotive coaling station	Link Belt Co.	4-30-09	12-31-10	96 670.13
26	Temporary engine yard, Wayne Junction	Armstrong & Latta Co.	1-22-08	6-30-08	51 571.60
27	Temporary freight yard, Nineteenth and Indiana	Reilly & Riddle	10- 4-07	5-30-08	40 381.40
28	Car-cleaning yard, Huntingdon St.	Edw. Fay & Son	7-13-08	6-30-09	53 326.82
29	Engineer's office, Huntingdon St.	Edw. Fay & Son	7-12-07	12-31-07	8 920.94
30	Coal pocket yard, Ninth and Berks	Wm. Steele & Sons Co.	5-25-08	3-31-09	273 578.29
31	Coal pocket yard, Tenth and Norris	Wm. Steele & Sons Co.	10-29-08	6-30-09	42 884.33
32	Masonry, etc., freight yard, Tenth and Berks	Armstrong & Latta Co.	10-16-08	5- 7-10	70 350.03
33	Signal bridges, Broad to Norris	Steward & Stevens	7- 8-09	2-28-10	4 155.92
35	Drainage, York St. Yard	O'Toole, Walls & Dempsey	10-24-08	8-31-09	2 762.83
36	Fences and gates, Berks to Broad	W. W. Lindsay & Co.	5-13-09	4-30-10	14 029.35
38	Signal towers, Green to Norris	Thos. J. Trafford	10-18-09	2- 7-11	8 567.46
39	Store house, Ninth and Green	Geo. A. Glenn & Co.	3- 2-10	2-28-11	27 034.15
41	Engine water supply, Ninth and Green	Burd P. Evans & Co.	1-25-10	2-28-11	6 107.27
46	Coal yard, Hunting Park Ave.	Enos L. Seeds	12-23-10	6-30-11	18 884.26
47	Signal bridges, Green to Norris, Tioga Section	L. F. Shoemaker & Co.	5-24-10	11-29-11	12 301.65
48	Tool house, Tenth and Diamond	Fred. A. Havens & Co.	4-22-10	8-31-10	3 583.70
53	Platforms—Powers, Weightman, Rosengarten	Belmont Iron Works	6-18-09	2- 4-11	5 494.00
54	Coal pockets—Powers, Weightman, Rosengarten	Burd P. Evans	2-15-11	4-29-11	1 842.99
E.O. 57	Girard Avenue Station	Irwin & Leighton	10-20-11	8-31-12	54 602.40
E.O. 35	Signal towers, Broad to Norris	Armstrong & Latta Co.	11-22-09	7-30-10	10 820.97

* Contractor defaulted—$35 627.09 recovered from sureties.

† Contractor defaulted—$10 048.31 recovered from sureties.

TABLE 2.—LIST OF CONTRACTS WITH CITY.

No.	Description.	Contractor.	Date of contract.	Date of final estimate.	Amount.
101	Sewers, 13th, Dauphin to Cumberland	Millard Cons. Co	8-27-07	7-27-08	$29 497.98
102	Sewers, on 16th St., and from 16th to 17th on Allegheny Ave	David McMahon	8-27-07	8-29-08	33 861.39
103	Sewers, Allegheny Ave., from 17th to 19th; Nineteenth St., Allegheny Ave. to Westmoreland	Millard Cons. Co	8-27-07	11-18-08	46 927.39
104	Sewers, Nineteenth, Westmoreland to Venango; Venango, 19th to 20th	Millard Cons. Co	8-27-07	11-18-08	71 100.92
105	Sewers, Venango, 20th to 21st; on 21st to Blabon, Hunting Park Ave	Millard Cons. Co	8-27-07	11-18-08	36 602.56
108	Street changes, Fairmount to Columbia Ave	McNichol Paving & Cons. Co	10-29-09	5-24-12	122 833.27
109	Street changes, Columbia Ave. to Broad	Am. Paving & Cons. Co	9-21-08	11-23-10	110 756.42
110	Street changes, Allegheny Ave. to Ontario	McNichol Paving & Cons. Co	10-29-09	11-28-11	134 338.60
111	Street changes, Ontario to Hunting Park Ave	McNichol Paving & Cons. Co	10-29-09	11-28-11	43 125.00
115	Street changes, Montgomery Ave	William A. Mundy	11-24-11	2-20-12	2 185.75

In order to provide for the car load freight business of the freight yards during construction, a temporary freight yard was constructed on property of the Railway Company at Nineteenth Street, capable of holding 163 cars, and a temporary engine yard at Wayne Junction. Work on the freight yard was begun in October, 1907, and finished on May 30th, 1908. The total cost of grading, drainage, and paving, exclusive of the track work, was $40 380.40. Work on the engine yard was begun on January 7th, and finished on June 30th, 1908. The total cost of grading, drainage, engine house, coaling station, water tanks, ash pits, etc., exclusive of the track work, was $46 501.60.

On the completion of the elevation of the tracks, the City was credited with the amounts which it had paid for the construction of these yards, less an amount agreed on, representing the depreciation of the tracks, in the case of the freight yard, and of the tracks and buildings, in the case of the engine yard.

Sewers.

In August, 1907, work was begun, practically at the same time, on the construction of by far the majority of the sewer work connected with the change in grades of the streets. The work is described very briefly under the following contracts:

Contract No. 101.—Sewer on Thirteenth Street from Dauphin to Cumberland: This was required to drain the depression caused by the lowering of the intersection at Thirteenth and Cumberland Streets.

Contract No. 102.—Clearfield Street east of Sixteenth; Sixteenth Street from Clearfield Street to Allegheny Avenue, and on Allegheny Avenue to Seventeenth Street: This was the outlet section of the main system for draining the depressed streets in the Tioga District, extending as far north as Nicetown Station.

Contract No. 103.—Allegheny Avenue from Seventeenth Street to Nineteenth Street, and Nineteenth Street from Allegheny Avenue to Westmoreland: This is the second section of the main sewers for draining the Tioga District.

Contract No. 104.—On Nineteenth Street from Westmoreland to Venango, and on Venango from Nineteenth to Twentieth: This is the third section of the main system for draining the depressed streets in the Tioga District.

Contract No. 105.—On Venango Street from Twentieth to Twenty-first, on Twenty-first Street from Venango to Blabon, on Blabon from Twenty-first Street to Hunting Park Avenue; on Hunting Park Avenue from Blabon to the railroad: This is the last section of the main sewers in the Tioga District, and taps the depression on Hunting Park Avenue under the railroad.

The sizes, costs, and other data in reference to the sewers built under Contracts 101 to 105 are shown on Table 3.

In addition to these, sewers were constructed in conjunction with Contracts Nos. 108, 109, 110, and 111, covering the smaller sewers in connection with the work of lowering the streets along the whole line of the work. Table 3 contains a summary of the entire cost of the sewer work, including inlets, connections, etc., and showing for each contract the length of the sewers and the total cost of the sewer work.

The construction of these sewers presented no unusual features. The work was executed in accordance with the standard plans and specifications of the Department of Public Works, Bureau of Surveys, of the City of Philadelphia.

Method of Construction.

The general character of the construction consists: First, of masonry walls and fill, between Green and Brown Streets, between Jefferson and Broad, and between Seventeenth and Indiana and the Richmond Branch, with steel bridges over the streets, carrying four and five tracks, respectively; and, second, a four-track steel viaduct over Ninth Street between Brown and Jefferson Streets.

Work was begun between Columbia Avenue and Broad Street in January, 1907, by diverting the temporary travel to two temporary tracks located as closely as possible to the west side of the 66-ft. right of way. The retaining walls on the east side, with the eastern halves of the bridge abutments, were next built, and a temporary trestle for two tracks was constructed alongside of them; and approximately one-half of the permanent bridges were erected, so that two tracks on the new high level could be placed in operation. Access to this high level was made by the permanent 1% grade from Broad Street and a temporary 2.5% grade from Columbia Avenue to Norris Street. Crib-work was placed along the western edge of the trestle to a height of about 8 ft., and as much fill as possible was made between the crib

and the wall around the trestle before travel was placed on the trestle. On the completion of the temporary tracks on the high level, schedule travel was transferred to them and abandoned on the low level. The western retaining walls and the rest of the abutments were then completed with the fill and the remainder of the bridges. The fill was generally made by carting in from the cross streets before the abutments were finished, and completed after the abutments were built by raising it over them with a clam-shell bucket and derrick. The permanent tracks were then laid on the new fill on the west side, and schedule travel was transferred to them; the temporary tracks on the trestle were removed; the ties, guard-rails, and stringers of the trestle were taken out for use at other points; the fill was completed, and the permanent tracks were laid in their final position. This same method was followed at all other points where masonry and fill construction was used, except that, in the Tioga District, between Seventeenth Street and the Richmond Branch, the method was reversed, the work being started on the west side first.

TABLE 3.—Sizes and Shapes of Sewers, and Costs on Each Contract.

Contract No.	Size, in feet.	Shape.	Invert.	Other particulars.	Cost per linear foot.	Length, in feet.	Total length, in feet.	Total cost.
101	5	Circular	Shale brick.	....	$24.67	572.80		
	4	"	" "	....	17.26	512.50	1 085.30	$29 497.98
102	6	"	Stone block	Rock section	27.00	1 070.50	1 070.50	33 861.39
103	6	"	" "	" "	29.00	868.89		
	6	"	Shale brick	" "	30.00	531.11	1 400.00	46 927.39
104	6	"	" "	Reduced cradle.	31.00	88.00		
	6	"	" "	In tunnel	54.00	170.00		
	6	"	" "	Rock section	42.00	297.89		
	5½	"	" "	" "	30.00	550.00		
	5	"	" "	" "	24.00	552.83		
	4¾	"	" "	Earth or rock	20.00	413.67	2 072.39	71 100.92
105	4¾	"	....	" "	21.50	530.40		
	4	"	....	" "	18.00	610.00		
	3	"	....	" "	16.50	687.64	1 827.04	36 602.56
108	..	....	....	....	....	....	5 155.27	25 913.77*
109	..	....	....	....	....	....	2 040.60	14 842.50*
110	..	....	....	....	....	....	2 834.50	14 872.97*
111	..	....	....	....	....	....	820.47	3 059.15*
Totals...	..	....	....	....	....	....	18 306.07	$276 678.63

* Does not include cost of inlets or similar details.

In the construction of the steel viaduct between Brown and Jefferson Streets, the foundations for the two outside lines of columns were constructed with the two tracks carrying schedule travel in the

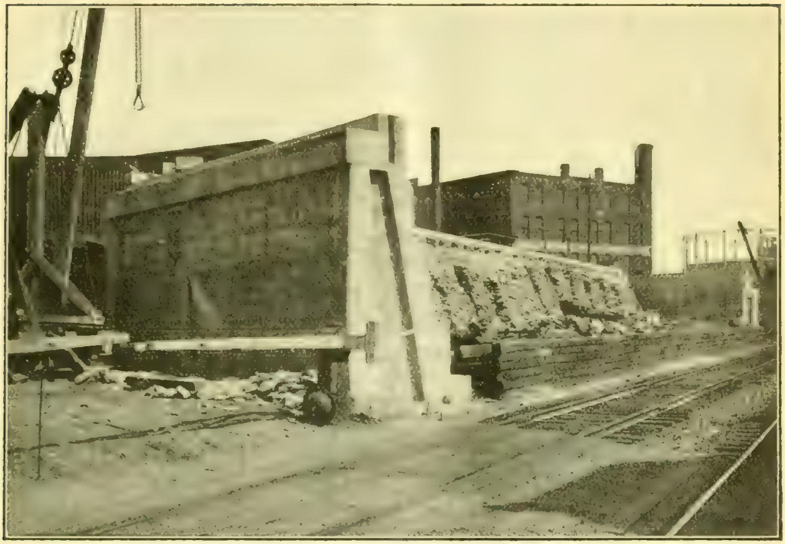


FIG. 2.—ABUTMENT AND DRY STONE PACKING, EAST SIDE.

FIG. 3.—ERECTING BRIDGES, EAST SIDE.

center of the 70-ft. street. One track was then placed on the west side of the street, as close to the houses as possible, the other was moved to the east, and the center line of foundations placed. A third track was then built on the west side, and schedule travel was abandoned on the eastern track, which was allowed to remain, to be used in the erection of the eastern half of the steelwork which was next completed. Two permanent tracks were then placed on the completed eastern half of the viaduct, and schedule travel was transferred from the low to the high level. The western side was then erected, completed, and the remaining two tracks were laid.

Temporary Tracks.

Before beginning work, the Railway Company had two tracks on which schedule trains were operated between Green and Cumberland Streets and four tracks from that point to Wayne Junction. There were also two additional tracks used for siding purposes between Girard Avenue and Cumberland Street.

From the time that the main tracks on the street level were disturbed for construction purposes, until the permanent tracks were laid on the high level, all the charges and maintenance were considered as temporary tracks. The instructions of the management were that there must be at all times two tracks in proper condition to operate schedule trains. Only enough material was ordered to carry out the necessary transfers of traffic and to replace that which was not fit for relaying as the tracks were taken up and moved. The general method for providing for temporary traffic has already been described, and it is fair to say that, owing to the care exercised by the contractors, engineers, and the Operating Department, there was no interference with schedule traffic.

Retaining Walls and Abutments.

The part of the construction with masonry walls and fill consisted generally of retaining walls on each side of the 66-ft. right of way, with vertical faces on the lines. It was absolutely necessary to place these walls vertically on the right-of-way lines between Columbia Avenue and Broad Street, as the plans provided for five tracks with 13-ft. centers in this territory, and the same construction was used at other points. As private property adjoined the right of way, there was not room to erect forms for concrete work without trespassing, and large

rubble masonry was indicated and used. Where retaining walls faced on streets, they were built of 1:3:6 concrete with granolithic washed faces and scored with horizontal lines. The same construction was used for bridge abutments. The typical retaining wall was as shown by Fig. 5.

The rubble work (known as third-class masonry) was built under the following specification, the mortar being of 1:3 Portland cement, the stone being bedded in mortar, and the vertical joints grouted with 1:3 grout:

"Third-class masonry shall be formed of approved quarry stone of good shape and good flat beds. No stone shall be used in the face of the walls less than 6 in. thick, or less than 12 in. in their least horizontal dimensions.

"Headers shall generally form at least one-fifth of the faces and backs of the walls, with a similar proportion throughout the mass when they do not interlock, and the face stones shall be well scabbled or otherwise worked, so that they may set close, and chinking with small stones be avoided.

"In walls, 5 ft. thick or less, the stones used shall average from 6 to 8 cu. ft. in volume, and the length of the headers shall be equal to two-thirds of the thickness of the wall; in walls more than 5 ft. in thickness, the stones used shall average 12 cu. ft. in volume, and the headers shall not be less than 4 ft. long. Generally, no stones shall be used having a less volume than 4 cu. ft., except for filling the interstices between the larger stones.

"In no case shall stones be used having a greater height or build than 30 in., and these stones must bond the joints above and below at least 18 in.; in all other cases the smaller stone used must bond the joints above and below at least 10 in.

"The stones in the foundation shall generally not be less than 10 in. in thickness, and contain not less than 10 sq. ft. of surface. The foundation shall consist of 1:3:6 concrete if so directed by the Chief Engineer."

The concrete used was of two kinds, 1:2:4 in bridge seats, pedestal blocks, etc., and 1:3:6 for main walls, foundations, copings, etc. The important and specially interesting points in the concrete specifications were as follows: Stone to be run of crusher, from ¼ in. to 1½ in. Sand graded from fine to coarse from ¼ in. down. Preference for machine mixing with cubical box type. Consistency to be such that when dumped in place, concrete will not require much tamping, but not wet enough to cause the mortar to

DIAGRAM SHOWING CONSTRUCTION OF MASONRY SECTION

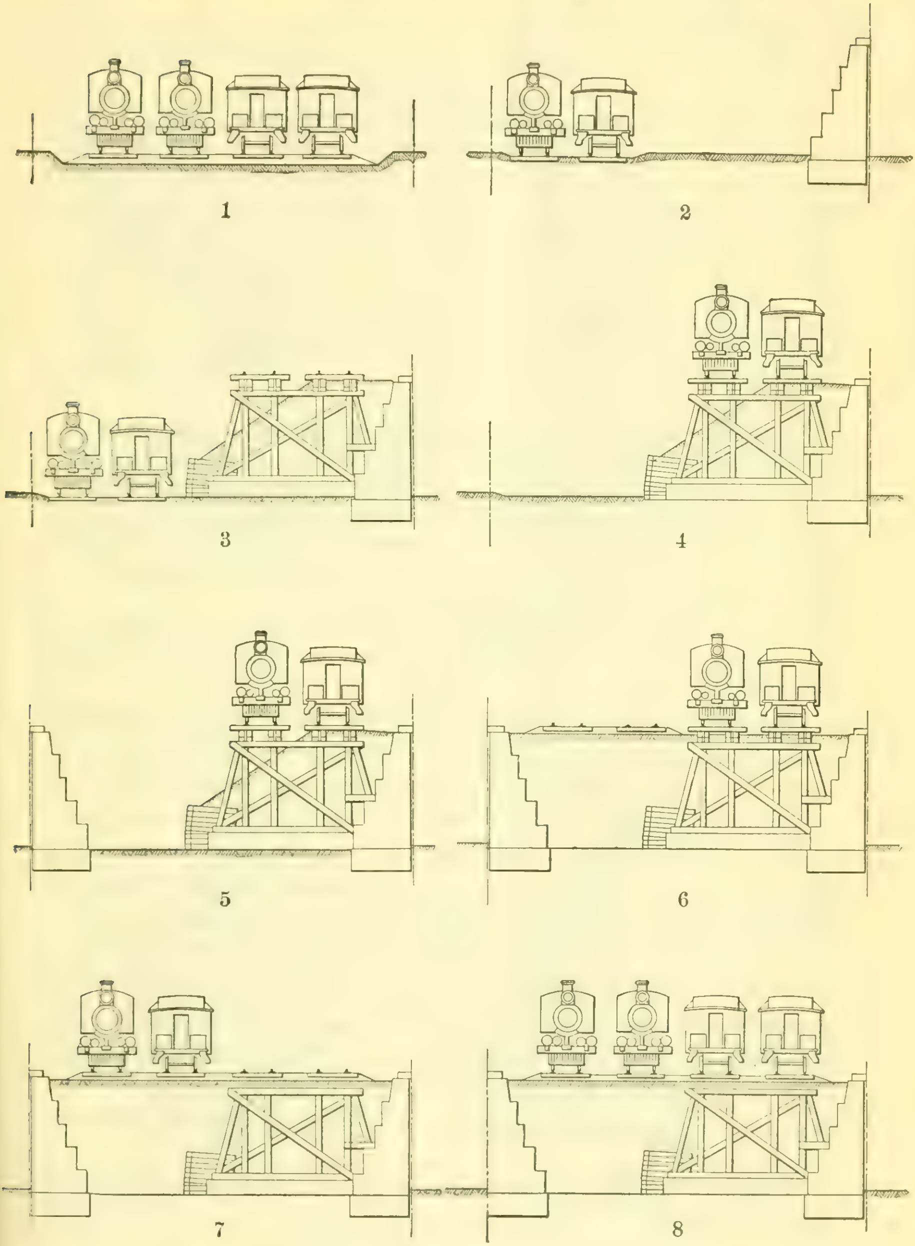


FIG. 4.

separate from the stone. Spaded down and tamped sufficiently to level off and quake freely like jelly.

With special face exposed to the street, the specifications were as follows:

"Surface of concrete exposed to the street shall be composed of 1 part cement, 2 parts coarse sand or gravel, and 2 parts granolithic grit made into a stiff mortar. Granolithic grit shall be granite or trap rock crushed to pass a $\frac{1}{4}$-in. sieve and screened of dust. For vertical surfaces the mixture shall be deposited against the face forms to a least thickness of 1 in., by skilled workmen, as the placing of the concrete proceeds, and thus form a part of the body of the work. Care shall be taken to prevent the occurrence of air spaces or voids in the surface. The face forms shall be removed as soon as the concrete has sufficiently hardened, and any voids that may appear shall be filled up with the mixture.

"The surface shall then be immediately washed with water until the grit is exposed, and rinsed clean and protected from the sun and kept moist for 3 days. For horizontal surfaces, the granolithic mixture shall be deposited on the concrete to a least thickness of 1.5 in. immediately after the concrete has been tamped and before it has set, and shall be troweled to an even surface, and after it has set sufficiently hard, shall be washed until the grit is exposed.

"All concrete surfaces exposed to the street shall be marked off into courses in such detailed manner as may be directed by the Chief Engineer."

The usual clauses regarding strength and finish of forms were used, and special fillets for the top edges of copings, pedestal blocks, and bridge seats were required. No reinforcement was placed in walls for temperature changes, but expansion joints were placed generally from 30 to 50 ft. apart. These were made with tongued and grooved joints on the faces of which there were corrugated asbestos boards. The use of embedded stone in the mass concrete was allowed, the stone not to exceed 6 to 8 cu. ft. in the foundations and 2 cu. ft. in the neat work. These were thoroughly cleaned selected stone embedded in the concrete immediately after it was placed. The stones were also used to form dowels bonding each day's work. The use of these stones was optional with the contractor, and though the quantity varied very much, they were generally put in. All copings were of concrete poured in place on top of the walls.

The prices obtained for the various kinds of rubble and concrete are shown in Table 4.

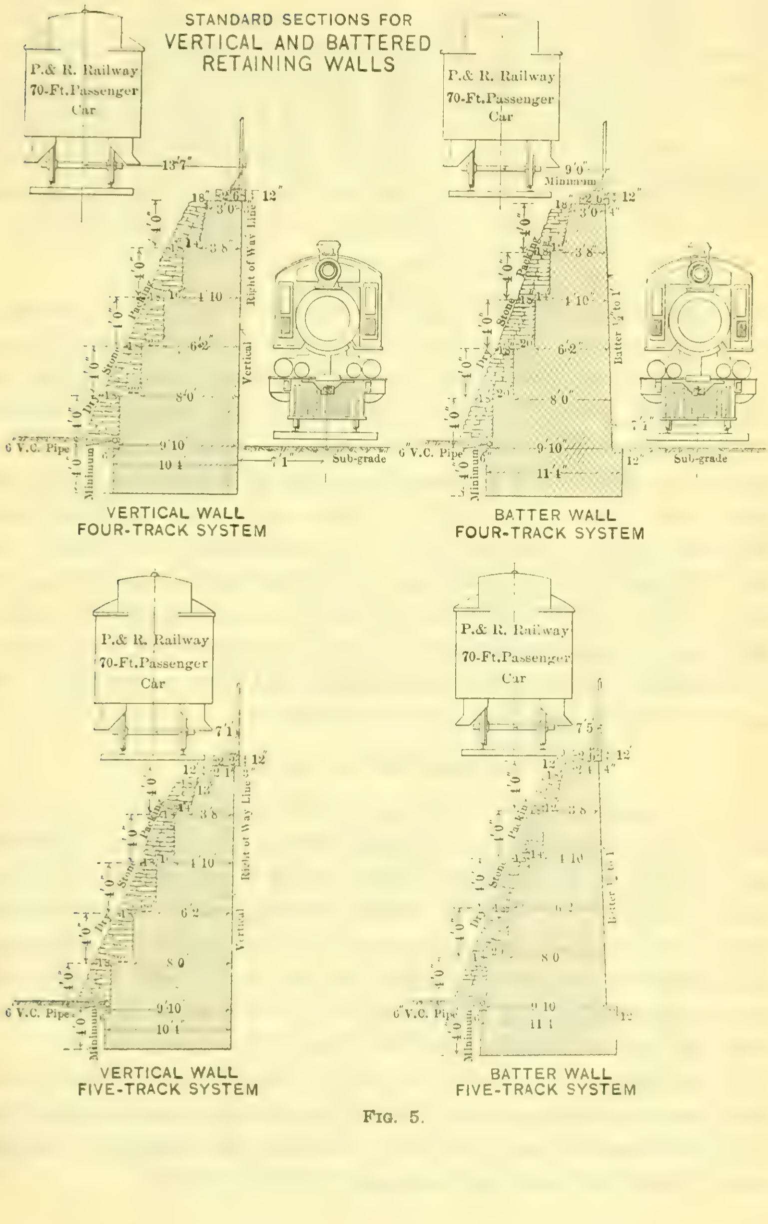

STANDARD SECTIONS FOR
VERTICAL AND BATTERED
RETAINING WALLS
P.& R. Railway
70-Ft.Passenger
Car
Right of Way Line
Vertical
6" V.C. Pipe
Minimum
Sub-grade
Batter 1/2" to 1'
VERTICAL WALL
FOUR-TRACK SYSTEM
BATTER WALL
FOUR-TRACK SYSTEM
VERTICAL WALL
FIVE-TRACK SYSTEM
BATTER WALL
FIVE-TRACK SYSTEM

FIG. 5.

TABLE 4.

Contract numbers	1	4	5	7	9	10	12	14	32
Third-class—neat	$6.00	$5.75	$6.50	$5.70	$5.25	$5.70	....	$6.50	....
" " —foundations	6.00	5.00	5.00	5.25	5.50	5.00	....	5.00	....
1 : 3 : 6 concrete—neat work	5.80	6.25	6.45	5.55	6.25	6.25	$6.30	6.45	$6.50
" " —foundations	5.50	5.60	6.00	5.25	5.63	5.50	6.30	6.00	5.75
" " —copings	7.25	7.50	6.75	7.75	7.25	7.00	7.50	6.75	6.75
" " —washed face	6.50	6.50	6.70	7.45	6.40	6.50	6.30	6.70	6.60
1 : 2 : 4 concrete	7.25	7.50	7.75	8.25	7.50	7.50	7.75	7.75	7.75
Dry stone packing	2.50	2.50	3.75	2.90	2.45	2.50	2.75	3.75	2.75
Arch concrete—1 : 2 : 4	....	....	7.50	....	....	....	....	....	....
Unclassified excavation	0.65	0.50	0.50	0.95	0.48	0.50	0.40	0.50	0.90

Drainage Back of Walls.

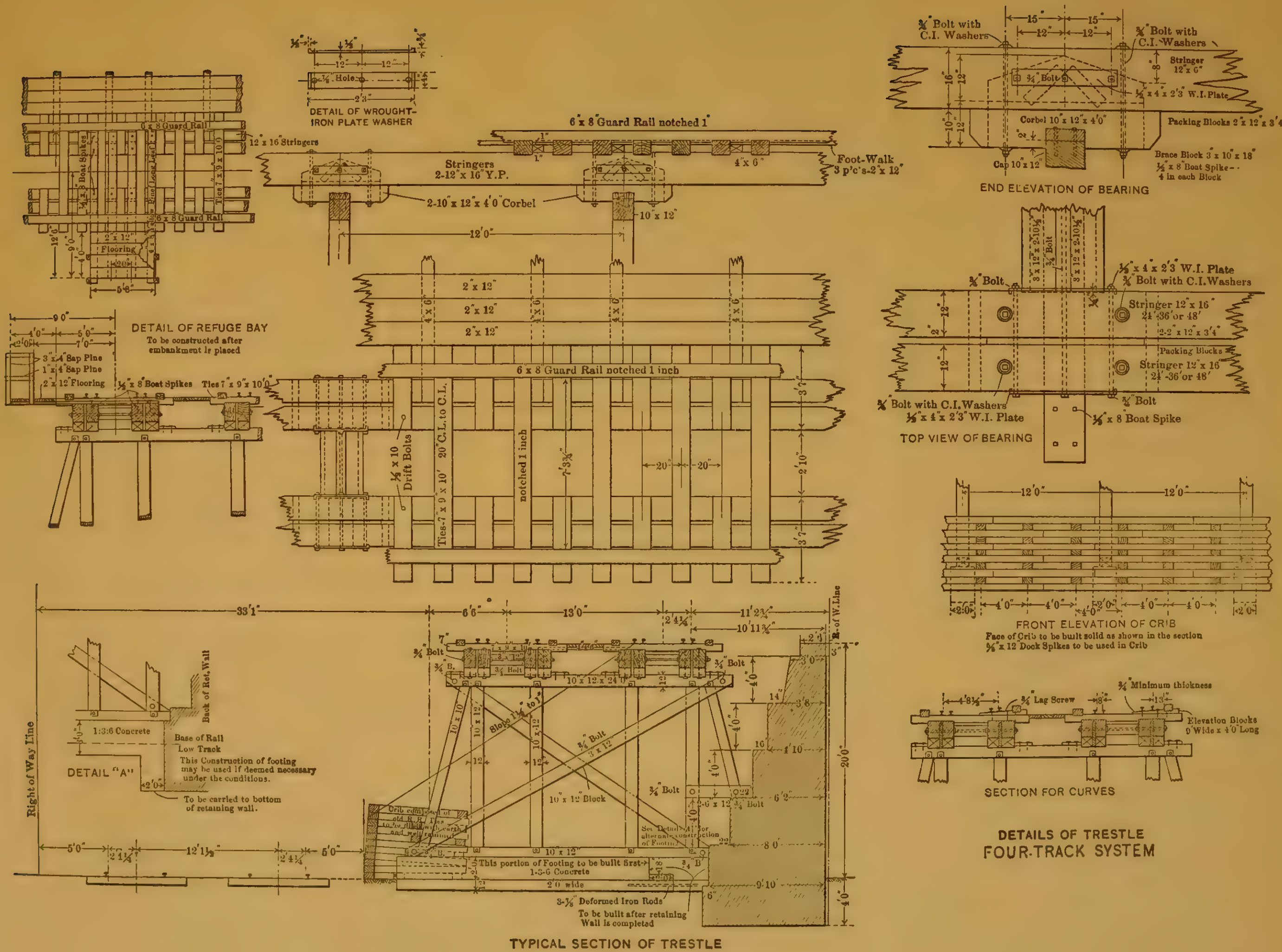
On account of the walls facing immediately on private property, or on the streets, it was decided to carry the drainage back of them, a step farther than the usual practice, in order to guard as far as possible from leakage through them to adjoining property or to the street, and the entire back of each wall, up to the subgrade of the tracks, was filled with a minimum thickness of dry-stone packing, the stone being from ¾ to 2 cu. ft. in volume, and placed by hand after the walls were finished and before the embankment was placed. As the third-class masonry walls were built, their backs were thoroughly dashed with 1 : 3 cement mortar. At the bottom of the dry-stone packing, 6-in. vitrified clay pipes with open joints were laid, with grades of about 1%, leading to the cross streets and there connected to the sewers. This drainage has proved very effective.

Temporary Trestle and Crib.

In the sections of the work constructed with masonry and fill, it was necessary to support two tracks between the bridges on trestle and then fill in as much as possible, using a crib about 8 ft. high with its face 5 ft. from the nearest running rail. The temporary trestle was built on concrete footings so as to reduce the settlement to a minimum and prevent wedging at the top in order to maintain proper track surface. It was constructed for two tracks in accordance with the general design shown on Plate LVI.

Long-leaf pine was used in the ties, guard-rails, and stringers, and these were all recovered when the fill was entirely completed and before the permanent track was laid. The caps, sills, posts, and bracing were of short-leaf pine, and remained buried in the fill.

PLATE LVI.
PAPERS, AM. SOC. C. E.
MAY, 1913.
WAGNER ON
TRACK ELEVATION, PHILADELPHIA, PA.



The prices paid for this work are shown in Table 5, and included everything above the concrete footings ready to lay track.

TABLE 5.

Contract numbers	1	4	5	7	9	10
Long-leaf yellow pine, per 1 000 ft. b. m.	$43.00	$44.50	$40.00	$43.00	$44.50	$42.00
Short-leaf yellow pine, " 1 000 " "	41.00	38.00	36.00	41.00	37.00	38.00
Wrought iron or steel, per pound	0.03	0.03	0.04	0.03	0.03	0.00

The average height of the double-track trestle was about 17 ft., and its average cost per linear foot was about $18.50, exclusive of the concrete footings.

The cribwork was covered by the following specifications:

"Where cribwork is required, it shall cover all temporary lumber work with the necessary filling and tamping required to retain slopes along partly made embankments or at other places, as may be directed.

"The lumber used in cribwork shall be placed as shown on the plans. It shall consist of second-hand lumber which is sufficiently sound to hold the drift-bolts.

"As the lumber is laid and drift-bolted, the embankment shall be filled in and thoroughly rammed. This work shall be paid for at the item price given in the proposal for cribwork per 1 000 ft. board measure, which price shall include all drift-bolts and the placing and ramming of the necessary embankment within the crib."

The prices obtained for the cribwork were as follows:

Contract numbers	1	4	5	7	9	10
Cribwork per 1 000 ft. b. m.	$15.00	$15.00	$20.00	$24.00	$25.00	$20.00

EMBANKMENT.

Embankments were built as soon as the footings for the temporary trestle were begun, and all excavated material from the foundations of walls and abutments was placed around them and in the crib, payment being made for excavation only. On the completion of the sections of the trestle between streets, the crib was carried up to its full height, embankment material was delivered on the cross streets, raised over the abutments with derrick and clam-shell buckets, and the fill completed around the trestle to its finished lines.

In some cases where excavation was available from the depressed streets, the trestle was planked, and the street grading contractor hauled the excavated material over it, and dumped it as part of his cost of excavation. With the exception of this, all material going

into embankments was furnished from outside the work and placed by the contractor at fixed prices, measurement being made on carts or wagons on delivery, each wagon load being measured by a representative of the contractor and an inspector who checked at the close of each day's work.

After schedule travel was placed on the temporary trestle, the remainder of the fill was made with teams hauling in from the adjoining streets, and after the abutments were completed the remaining material was raised over the abutment, as was done on the other side.

All material for embankment was inspected carefully and no ashes, cinders, or perishable material were allowed. Nearly all of it came from various building operations throughout the city.

The prices paid for embankment, delivered and placed by the contractor, were as follows:

Contract numbers..	1	4	5	7	9	10	12	14	32
Embankment.......	$0.20	$0.14	$0.45	$0.52	$0.10	$0.15	$0.10	$0.45	$0.175

Bridges.

All the bridges on the improvement carried railroad tracks, there being not a single highway bridge. Wherever possible, they were of deck construction, and, where through girders were required, the top of the girder was kept as low as possible, or the distance between tracks was spread to 14 ft.—the standard being 13 ft. All bridges were of the plate-girder type with solid steel floors either of built-up troughs or buckle-plates. The top of the steel on the floors was protected in all cases by some kind of water-proofing described later. Generally, all spans crossing streets had columns on the curb lines. The underside clearance over the streets established by ordinance was 14 ft. All masonry for supporting the steelwork was executed under separate contracts, the bridge contracts, however, covering all water-proofing and painting ready for the ballast.

The design of all the bridges was complicated seriously by the fact that they had to be planned so as to be erected in two sections, in order to carry travel on the high level on one side while the other side was under construction. This was specially difficult where the skews of the street crossings were great, and, in two cases, it was necessary to erect part of the steel over travel on the low level. The problem of water-proofing was also made more difficult on account of the provision for the double erection and the necessary joint.

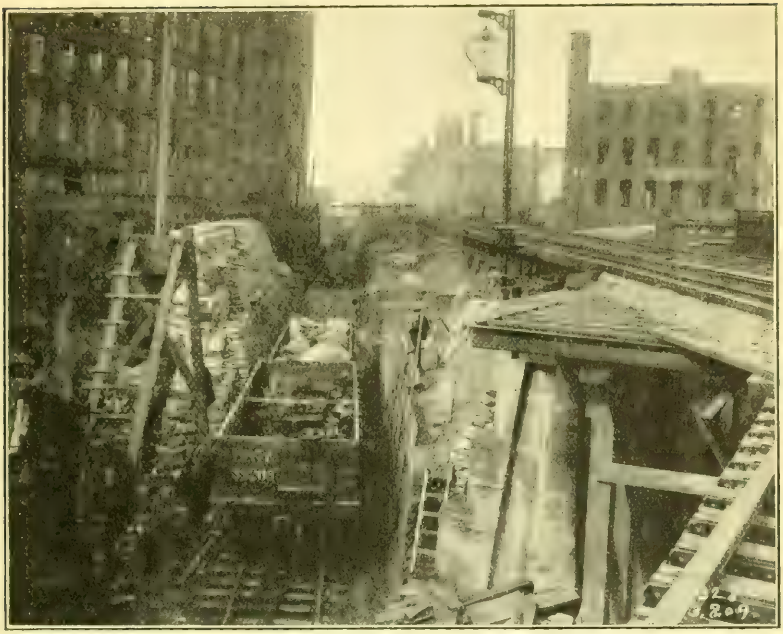


FIG. 6.—BUILDING WALLS, WEST SIDE.

FIG. 7.—FINISHING BRIDGES, WEST SIDE.

TABLE 6. DATA FOR BRIDGES.

Location.	Type.	Area, in square feet.	Weight of steel per square foot.	Cost per square foot.	Total cost.
CONTRACT NO. 8.—BROAD TO NORRIS STREETS.					
Norris St. (east)	Deck. 6-in. Z-floor	3 130	115.5	$4.92	$15 400
Norris St. (west)	Deck. 6 in. Z-floor	2 450	130.8	5.60	13 700
Tenth and Diamond	Part deck. Buckle-plate floor... Part half through. 12-in. trough floor	13 325	136.5	5.45	72 600
Susquehanna	Half through. Deep trough floor.	5 160	141.2	5.85	30 200
Colona	Longitudinal trough floor	3 340	126.0	4.74	15 800
Eleventh and Nevada	Half through. 12-in. trough floor.	8 680	157.0	6.40	55 500
Dauphin	Deck. Buckle-plate floor	4 100	117.0	4.61	18 900
Twelfth and York	Half through. Trough floor	7 750	148.5	6.30	48 700
Thirteenth and Cumberland	Half through. Trough floor	11 415	134.1	5.63	64 300
CONTRACT NO. 6.—MONTGOMERY TO OXFORD STREETS.					
Oxford St.*	Special half through. Trough floor	3 740	97.6	$3.50	$13 150
Columbia Ave.*	Special half through Trough floor.	18 000	103.4	3.55	64 067
Montgomery	Half through. Trough floor	3 700	125.0	4.25	15 740
CONTRACT NO. 1.—JEFFERSON TO GREEN STREETS.					
Green St	Half through. Trough floor	1 660	186.0	$6.20	$10 300
Engine passageway	I-beams and trough floor	3 630	103.0	3.60	13 100
Fairmount (west)	Half through. Trough floor	750	159.0	5.85	4 400
Fairmount (main)	Deck. 6 in. Z-floor	3 000	116.0	3.80	11 400
Fairmount (coal track)	Deck. 6-in. Z-floor	750	110.0	3.87	2 900
Fairmount (east)	Half through. Trough floor	960	134.0	6.10	5 864
Master St	Deck. Buckle-plate floor	3 050	109.0	4.00	12 200
CONTRACT NO. 11.—SEVENTEENTH AND INDIANA TO RICHMOND BRANCH.					
Allegheny Ave	Half through. Trough floor	9 165	153	$4.94	$45 393
Westmoreland	Half through. Trough floor	3 320	125	4.32	14 345
Nineteenth	Half through. Trough floor	7 910	150	4.91	38 920
Ontario	Half through. Trough floor	3 495	120	4.13	14 413
Tioga and Twentieth	Half through. Trough floor	11 070	146	4.81	53 282
Atlantic	Half through. Trough floor	3 535	120	4.10	14 652
Venango	Half through. Trough floor	3 440	149	4.10	14 096
Erie	Half through. Trough floor	7 380	140	4.57	33 697
Hunting Park	Half through. Trough floor	7 195	157	5.08	36 527

* Part of these bridges occupied by passenger station platforms.

At two points only was it possible to construct concrete arches. These will be described separately.

The designs and specifications were of the Philadelphia and Reading standard, which generally provide for a live load about equivalent to Cooper's E-55.

The dead weights assumed for the design of the ballasted floors were as follows, all in pounds per cubic foot: Ballast, 120; concrete, 140; asphalt, 90; lumber, 54.

The impact was by the following formula:

$$I = S\,\frac{300}{L + 300}$$

I = amount to be added to live-load stress;

S = calculated live-load stress;

L = length, in feet, of the loading which produces maximum stress in the member.

Unit stress = 15 000 lb. per sq. in., in tension.

In compression, 15 000 reduced.

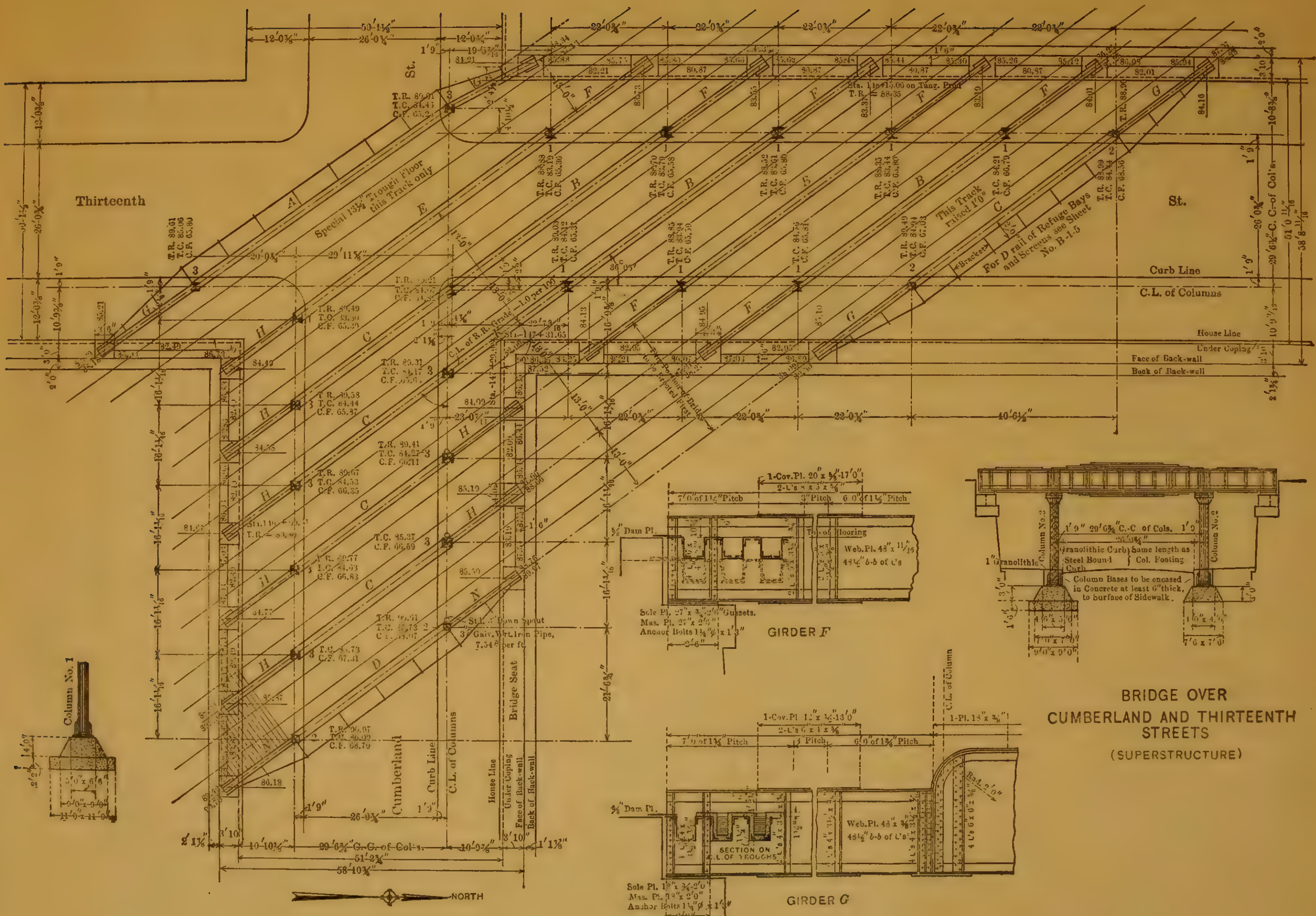
All steel was to be made by the open-hearth process, with a desired ultimate strength of 60 000 lb. for structural steel and 50 000 lb. for rivets; minimum elongation in 8 in. $= \dfrac{1\,500\,000}{\text{ultimate tensile strength}}$.

Very few of the bridges were distinctly of deck construction, on account of the lack of sufficient head-room, caused by the usual close clearances in grade-crossing work, where the procedure seems to be to squeeze the bridge construction out of existence. Where deck construction was impossible, half through spans were resorted to, with the top flange of the girders as close to the rail level as possible. In a number of cases it was necessary—especially on that part of the structure carrying five tracks—to introduce a deep transverse floor, so as to provide for necessary cross-overs in the tracks. The general type of one of the two styles of construction is shown on Plate LVII.

Table 6 shows the general data regarding the bridges on four different contracts and, in examining them, the conditions under which they were designed and the peculiar locations of many of them must be considered.

All columns located on the sidewalks, were required by the City authorities to have their base-plates far enough below the surface of the street to show only the main section of the column. All gussets were to be below the surface. The masonry contractors built the floorings up to the level of the base-plates, the bridge contractors, after setting the columns and lining up the steel work, encased the entire base of the columns in concrete which formed part of the surface of the sidewalk and a section of the curb.

Most of the bridges were erected with the usual derrick car, either by jacking it up to the high level, as was necessary in one case, or by



BRIDGE OVER CUMBERLAND AND THIRTEENTH STREETS

(SUPERSTRUCTURE)

running it in on the completed high-level approach, in others. When in position to command part of the bridge, the main steel members were run in between schedule trains on the low level, on cars as loaded at the shops, picked off quickly, and either put in place at once, if opportunity offered, or temporarily placed in the street and raised afterward. In some cases the contractors arranged for the railroad wrecker to assist in handling and placing the heavier girders, the time consumed in lifting from the cars and placing in position being very short.

The first halves of the bridges were always located in their permanent positions, no matter what the temporary alignment of the tracks was after leaving them, so that, when once placed, they required no further attention. In erecting the final half of each bridge, the same methods were used.

One of the requirements of the City, in approving the plans of the bridges, was the use of a solid shield or screen over the streets to prevent horses from seeing the moving parts of the locomotives. The height of these shields was finally agreed on as 5 ft. above the top of the rail, and, after considerable study, it was decided to use a cast-iron, ribbed plate, supported on a steel framework attached to the main bridge structure. In a number of cases where there were vacant lots adjoining the streets, these shields were run back on the retaining walls for a distance of 50 ft. or more, depending on the location. In all cases the shields were made part of the bridge contracts, and the costs were included in the lump-sum prices for the bridges.

Viaduct.

Under the terms of the ordinance, Ninth Street was vacated from Brown Street to Fairmount Avenue, and was opened to its full width of 70 ft. from Girard Avenue to Jefferson Street. Prior to the passage of the ordinance, the Philadelphia, Germantown, and Norristown Railroad owned a strip occupied by two tracks between Fairmount Avenue and Girard Avenue, and a right of way, 66 ft. wide, north of Girard Avenue. By the terms of the ordinance, all rights on the street surface owned by this Company were given over to the City, and the Railroad Company retained only the right to enter on the street at all times for renewals or repairs. The ordinance provided for a four-track steel viaduct through this territory, with a paved street

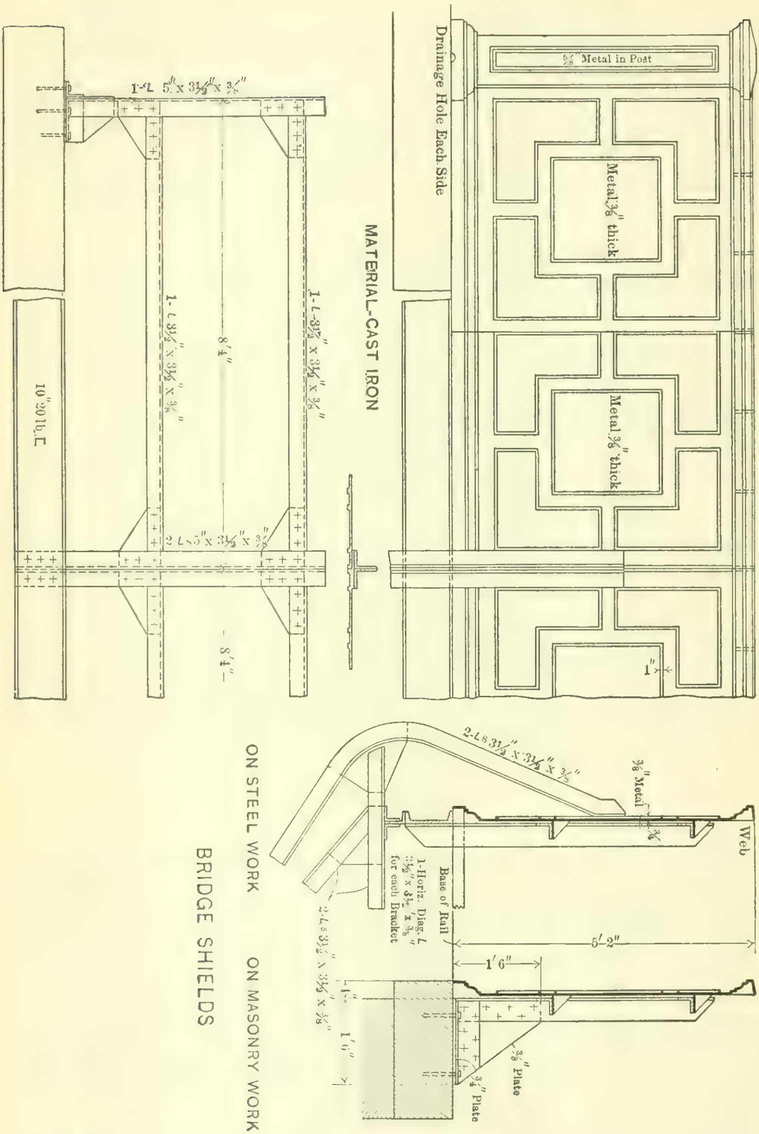

MATERIAL-CAST IRON
Drainage Hole Each Side
Metal in Post
Metal 3/8" thick
Metal 3/8" thick
1-L 5" x 3 1/2" x 3/8"
1-L 3 1/2" x 3 1/2" x 3/8"
1-L 3 1/2" x 3 1/2" x 3/8"
8' 4"
10" 20 lb. [
2-Ls 3 1/2" x 3 1/2" x 3/8"
Base of Rail
5' 2"
1' 6"
3/8" Plate
3/4" Plate
Web
ON STEEL WORK
ON MASONRY WORK
BRIDGE SHIELDS

FIG. 8.

beneath. The Railway Company paid the entire cost of the additional structure for the two extra tracks where it originally had but two.

The structure as built is a four-track steel viaduct supported on three lines of columns, just inside each curb line and in the center of the street. The columns support transverse girders joined over the center column, which in turn carry eight lines of longitudinal

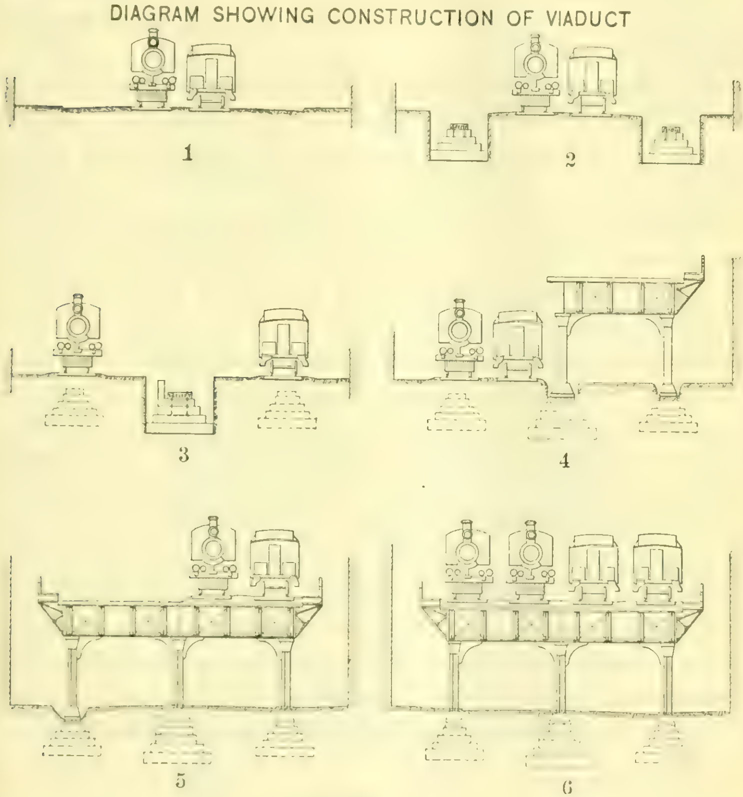


FIG. 9.

girders, spaced 6 ft. 6 in. on centers, and framing into the transverse girders. On the longitudinal girders, and at right angles to them, is a solid floor of 6-in. steel Z-bars and plates which is cut longitudinally, at about the center of the street, to allow the viaduct to be erected in halves. This floor has its troughs filled with concrete and is covered with 1.5 in. of asphalt mastic in turn supporting the ballast and stand-

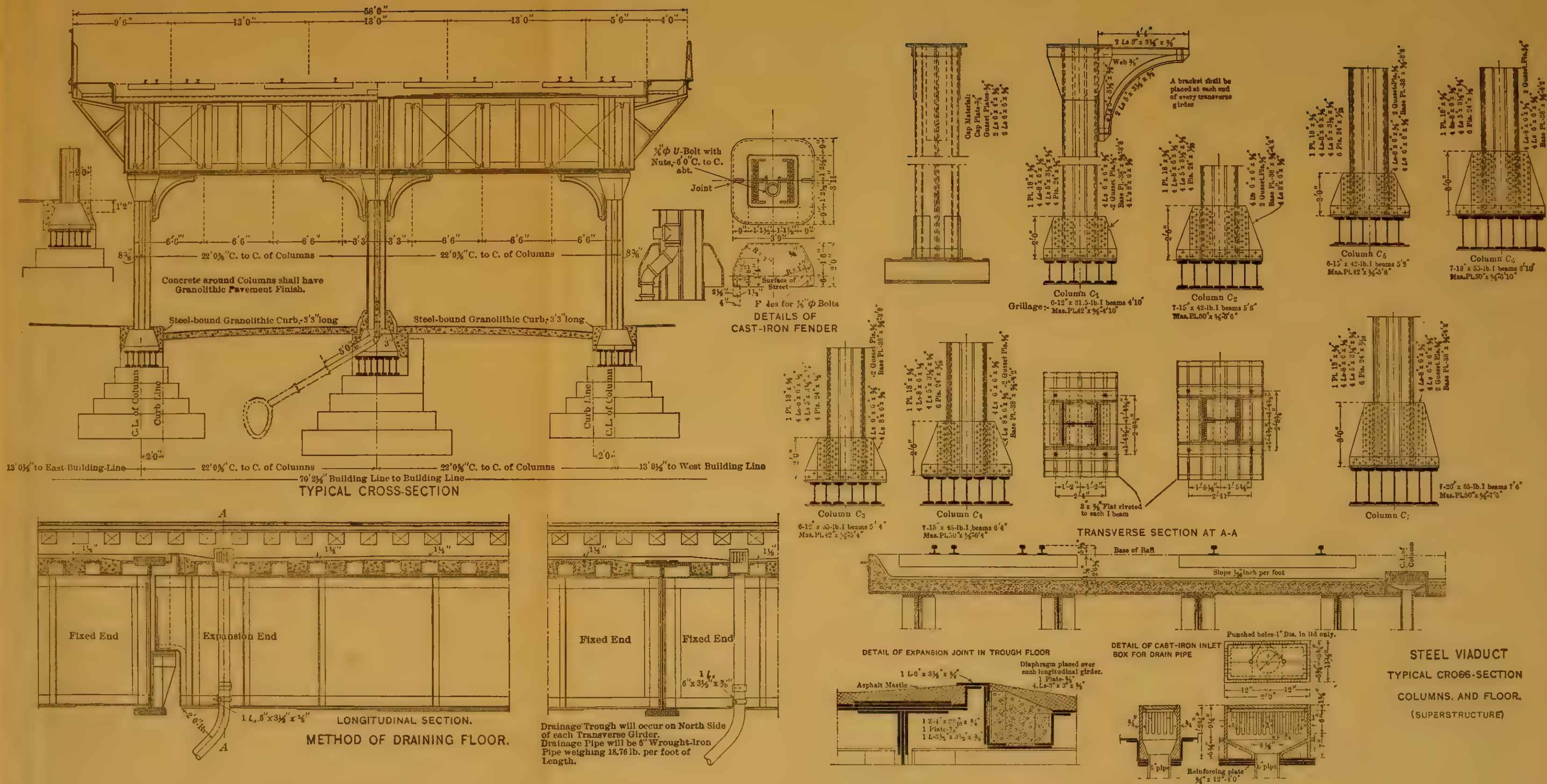
ard track. Sidewalks 4 ft. wide are carried on brackets on both sides outside of the dam plates. These have open floors with ½-in. open joints. The structure is designed to allow cross-overs to be placed in the tracks at any point, and the outside line of longitudinal girders is made of the same section as the others, so as to make it readily possible to provide in the future for siding connections.

The foundations for the columns of the viaduct were started under Contract 2, but the contractor abandoning his work, it was relet under Contract 2, Reletting.

With the tracks in the center of the street, the foundations for both outside lines of columns were constructed. The tracks were then moved as close to the west side of the street as possible, which just left room for entrance to the houses on the west side and for the execution of the work on the center foundations. These foundations were troublesome, not only on account of water which was encountered in considerable quantity between Girard Avenue and Brown Street, but also on account of the limited space available for their construction and the close proximity to passing trains. Comparatively little work was done under Contract 2 before it was abandoned, and therefore the prices given are those for Contract 2, Reletting. The bottom of the foundations was stopped between Girard Avenue and Brown Street generally on mixed gravel, and between Girard Avenue and Jefferson Street on gravel or hard clay. Throughout the length of the viaduct the depth of the foundations was controlled to a certain extent by the depth of a sewer which was required in the street before the permanent pavement was laid, and which could not be constructed before the foundations were built. The total cost of the foundation work was $151 631.20, which, reduced to the unit of square feet of viaduct, amounts to $0.76 as the cost of the substructure. The principal unit prices were:

Excavation	$1.65 per cu. yd.
1 : 3 : 6 concrete	5.50 " " "

After the completion of the foundations, the eastern half of the viaduct was erected, starting from Brown Street and working north. On account of the very close proximity to passing travel, the erection was a matter requiring the most careful consideration, and the manner adopted was one for which the contractors should receive much credit. On account of the condition of the work at the ends of the



STEEL VIADUCT

TYPICAL CROSS-SECTION

COLUMNS, AND FLOOR.

(SUPERSTRUCTURE)

viaduct, a considerable time elapsed between the erection of the first half and the completion of the whole structure. All steel for both sections was brought to the work on the street level, and the rate of progress, which under average conditions was 3 spans per day, was very good. Better time in erection would have been made but for the expansion-joint detail requiring riveting at the transverse girders before other spans could be raised.

In the layout of the viaduct, a standard span of 50 ft. was adopted, and this was used wherever possible, the odd span being placed adjacent to street intersections, which were always special.

On account of the light grades on the viaduct, and the expansion joints at intervals of about 150 ft., it was difficult to arrange for drainage. Low places were provided with cast-iron inlet boxes, to which 6-in. wrought-iron pipes were attached, following down the column and connecting directly with the sewer.

The method of erection of the viaduct planned by the McClintic-Marshall Construction Company was based on:

First. The determination of a method that would come as nearly as possible to being absolutely safe for the passage of trains; and

Second. Economy of time and money.

The method proposed, approved, and adopted was the use of a steel cantilever traveler running on top of the erected viaduct, the erection being accomplished with the aid of two 15-ton traveling electric cranes with one intermediate bridge carrying four 12-ton hoists. The traveler had been remodeled from a steel cantilever traveler previously used for viaduct erection, a few of the truss members having to be reinforced, and an entirely new system of top construction made. The total weight of structural steel in the traveler was 150 tons. The power used was alternating current furnished by the Philadelphia Electric Company, which established connections where convenient, approximately 800 ft. apart. Four heavily insulated flexible wire cables were connected at these stations, and these cables were carried on a reel suspended from the rear of the traveler, the reel being paid out as the traveler advanced, and rewound when new connection was established. The traveler was erected and taken down with a heavy locomotive crane, which also erected enough of the viaduct to provide a platform on which to build the traveler and on which to start work.

This locomotive crane also erected the portion of the viaduct wider than four tracks, between Brown and Parrish Streets. A 50-ft. boom placed on the front end of the traveler erected the extra width of steel between Master and Jefferson Streets. On the second half, it was necessary to run the traveler on a slight curve between Master and Jefferson Streets, and there was no difficulty in accomplishing this. The traveler had a 70-ft. anchor arm and a 120-ft. cantilever arm. When moving ahead, the cranes were at the extreme rear end of the traveler, thus helping to furnish counterweight against overturning. The traveler was moved with the aid of a heavy hoisting engine placed on a platform on the rear of traveler, and a single set of double wire-cable falls moved it with ease. The reaction on the wheels at the main point of support, when moving, was very heavy, being 272 000 lb. on the heavier side. After the traveler was moved ahead, and before the crane could move to pick up any load, the columns or front post extension in front of the traveler had to find a bearing on blocking previously placed on the street at the point to which it was being moved. The actual moving, including knocking out the blocking, the moving itself, and the reblocking, did not take more than 15 or 20 min., that is, 15 or 20 min. after picking up iron in one position the traveler could be moved ahead and be ready to pick up iron for a new span; in general, two spans, or about 100 ft., being erected for each move.

The structural steel was shipped from the contractor's Pottstown plant, being loaded on cars in the exact order in which it was wanted, so that, when delivered to the traveler, the first car received contained the longitudinal girders, the next car contained the transverse girders, columns, and cross-frames for the girders, and the third car contained the trough floor, railing, etc., all for the span being erected. These cars were delivered on an abandoned track directly under the work to be erected—the track being approximately midway between the two lines of columns on which the work was being placed. As the material was unloaded the empty cars were dropped down under the viaduct already erected, the overhead clearance permitting this, though in many cases it would not permit a loaded car to pass beneath the viaduct.

The method of erecting in detail was as follows: The rear electric crane would pick up a longitudinal girder and hang it on one of the chain hoists carried on the trolley on the intermediate bridge. The

rear end of the girder would be connected immediately to the transverse girder of the previous bent before the electric crane cut loose—thus the rear electric crane would set the four longitudinal girders. Meantime, the forward electric crane would erect the two columns and pick up the transverse girder preparatory to connecting it to the longitudinal girders being erected. The transverse girder would be brought in against the ends of the longitudinal girders and set on top of columns, there being in general about 2 in. play between the tops of the longitudinal girders and the top flange of the transverse girder, thus not requiring the longitudinal to be hung at the precise height. The four chain hoists supporting the forward ends of the longitudinal girders would then be slacked off, one man to each chain hoist, so that the girders would be seated on the longitudinal girders and the fitting up bolts entered. The forward crane would then pick up the cross-frames and place them on the longitudinal girders just erected, when both cranes would place the frames in position. The forward crane would then pick up the trough floor, while the rear crane attended to moving ahead any timbers required for the track, these having been snaked ahead with line from the hoisting engine. When handling the 61-ft. girders across Girard Avenue, one crane was used on each end of the girder, this being also necessary on a few of the other special girders. The use of the intermediate bridge, carrying the four chain hoists, obviated the use of temporary bents on which to set the longitudinal girders, and, in addition, was much better, as it readily gave movement in all three directions, as desired, as the bridge was carried on the trucks on the crane runway beams, and each hoist was hung from a trolley running on the bottom flange of an I, and the chain hoists themselves permitted the small vertical movement required for adjustment with little labor.

In general, three spans were raised per day, requiring gangs working ordinarily 6 hours. Where there were four spans, without encountering expansion joints, these were raised in less than 7 hours. In one day it was impossible to raise more steel than between two expansion joints, as the longitudinal girders had to be riveted, as explained previously.

The general figures of interest in connection with the viaduct were as follows:

The contract price was $772 000, including everything from the top

of the concrete footings to the ballast. This included all drainage, water-proofing, and steel grillages for the top of the footings.

Total weight of steel	30 010 000 lb.
Floor area of viaduct	197 300 sq. ft.
Weight of steel per square foot	152 lb.
Cost of water-proofing per square foot	$0.24
Total cost of work per square foot	$3.91

Concrete Arches.

There were only two points on the line where arches over the streets were possible, namely, at Berks and Norris Streets, the streets being 50 ft. wide and the bridges carrying five tracks at Berks and six tracks at Norris Street. These arches were of concrete, and, like all the other bridges, were constructed in two sections longitudinally, and were water-proofed. The general dimensions were as follows:

Berks Street:	Span	50 ft.
	Rise	10 ft. 9⅝ in.
	Thickness at crown	3 ft.
	Width	65 ft. 8 in.
Norris Street:	Span	50 ft.
	Rise	1 ft. 1⅛ in.
	Thickness at crown	3 ft.
	Width	82 ft. 7 in.

At Berks Street, five layers of Genasco Positive Seal Felt in Genasco Compound were used for water-proofing, protected with a layer of 1:3 cement mortar 1 in. thick. At Norris Street, there was used 1.5 in. of asphalt mastic, made by mixing 1 part of Barber Asphalt Company's Compound No. 483 with 4 parts of sand and screenings. This was laid in two ¾-in. layers, each, breaking joints. The compound had the following properties: Bitumen soluble in CS_2, 97%; not more than 0.5% volatile at a temperature of 350° Fahr. for 5 hours; does not flow at 212° Fahr. nor become brittle at — 15° Fahr.; not acted on by H_2SO_4 in 7 hours (25% solution). The water-proofing of both these bridges has been very satisfactory. It cost as follows:

Berks Street	23 cents per sq. ft.
Norris Street	30 " " " "

The prices for the concrete in the arches were as follows:

1 : 2 : 4 concrete in arch ring, including centers	$7.50	per cu. yd.
1 : 3 : 6 concrete in copings	6.75	" " "
1 : 3 : 6 concrete in abutments—street finish	6.70	" " "
1 : 3 : 6 concrete in foundations	6.00	" " "

Water-Proofing Bridges and Viaduct.

All the bridges and the viaduct cross City streets or are over stations, as is the case at Columbia Avenue, and it was very desirable that they should be impervious to water, not only for the protection of the public, but also for the preservation of the metal. In a large number of cases, the elevation of the curbs of the streets beneath, and the profile of the tracks above, was fixed within such close limits as to make it difficult to provide proper water-proofing details. The writer believes that one of the most important features of water-proofing design is to get the water away from the structures as fast as possible, and, where the grades of the track are light, this is difficult without using up valuable head-room.

In the first bridges designed and erected, where trough floors were required, the whole of the upper surface of the metal was covered with 1.5 in. of asphalt mastic, applied in two layers to the vertical and horizontal surfaces of the steel floor. This was sloped in the troughs to carry the water to a nipple passing through the steel floor emptying into a wrought-iron trough beneath the floor, and then to down-spouts to the street gutters. If the structure was a deck bridge, the steelwork was first leveled up with Portland cement concrete, made of $\frac{3}{4}$-in. stone and mixed 1 : 3 : 6, on which was placed five layers of "Hydrex" or similar water-proofing felt, laid in asphalt compound and protected with a course of hard brick laid flat in the compound. After laying the brick, the compound was poured in the joints and mopped over their tops. The drainage from this type of water-proofing was taken over the back-walls and through the dry packing already described to the sewers in the streets. The nipple proved to be a somewhat troublesome detail, and it was difficult to get it tight, the water frequently finding its way around it. These bridges also developed some leaks along the main girders, due to the separation of the mastic from the girder webs; but the leaks were bad in only a few cases, and have been largely corrected by mopping hot pure asphalt on the

mastic along the girder webs, spreading burlap over it, and then applying another mopping of asphalt. The deck bridges with the felt and compound are much tighter.

The second lot of bridges designed and erected differed from the foregoing in that the troughs were filled with cement concrete to the top of the rivet heads, and a smooth coat of asphalt mastic, 1.5 in. thick, was put on in two layers and haunched up against the girder webs and under a flashing angle riveted to the webs. The same method was used on the viaduct. The drainage on the bridges is to one or both ends, and over the back-walls, depending on the grades. On the viaduct, it is to cast-iron inlet boxes and thence through wrought-iron down-spouts to the street level, and in vitrified clay pipes to the sewer. These bridges have generally been tight, except in a few cases where there has been a separation of the mastic from the flashing angles and webs, and these defects have been remedied by cutting out the cracks, filling them with hot pure asphalt, and finally covering them with burlap mopped with asphalt, as previously described. On a portion of the viaduct, the mastic cracked badly on the haunching, and required considerable repairing. This, it is believed, was due to the improper proportioning of the ingredients, as it occurred when the work was first started. In several other cases, leaks have occurred where it was necessary during construction to push the work irrespective of the weather conditions, and in other places where it was difficult to make a good joint between old and new work. It was found to be very difficult to clean properly the surfaces on which either the new compound or the new mastic was added, and it is thoroughly believed that without adequate cleaning and drying it is impossible to bond surfaces with any asphaltic water-proofing material. The necessity of using an asphalt material which has a very low brittle point and a sufficiently high melting point simply to prevent running in hot weather, has been apparent in this work, and is indicated especially for similar work where the structure is subject to vibration. Recent work has also shown the necessity of using a joint, between the asphalt mastic and the metalwork of the structure, consisting of a pocket of pure elastic asphalt.

The estimated costs of the water-proofing were obtained by a careful analysis of the lump-sum figures for the bridges, and show a

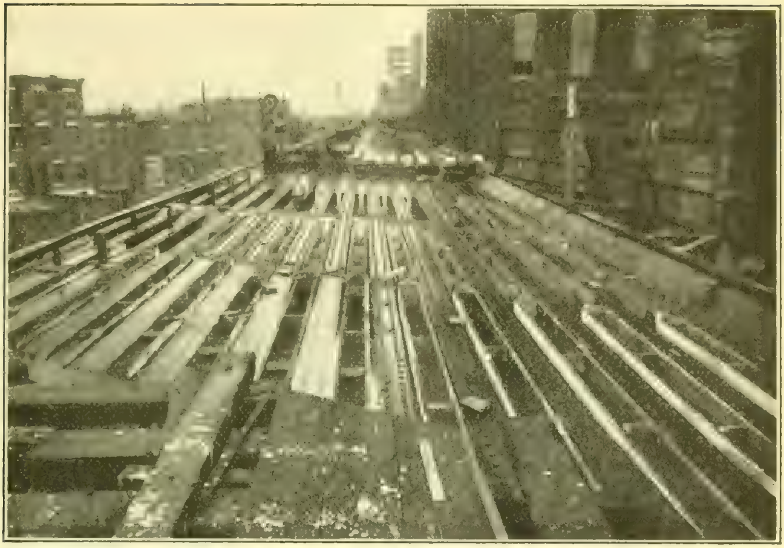
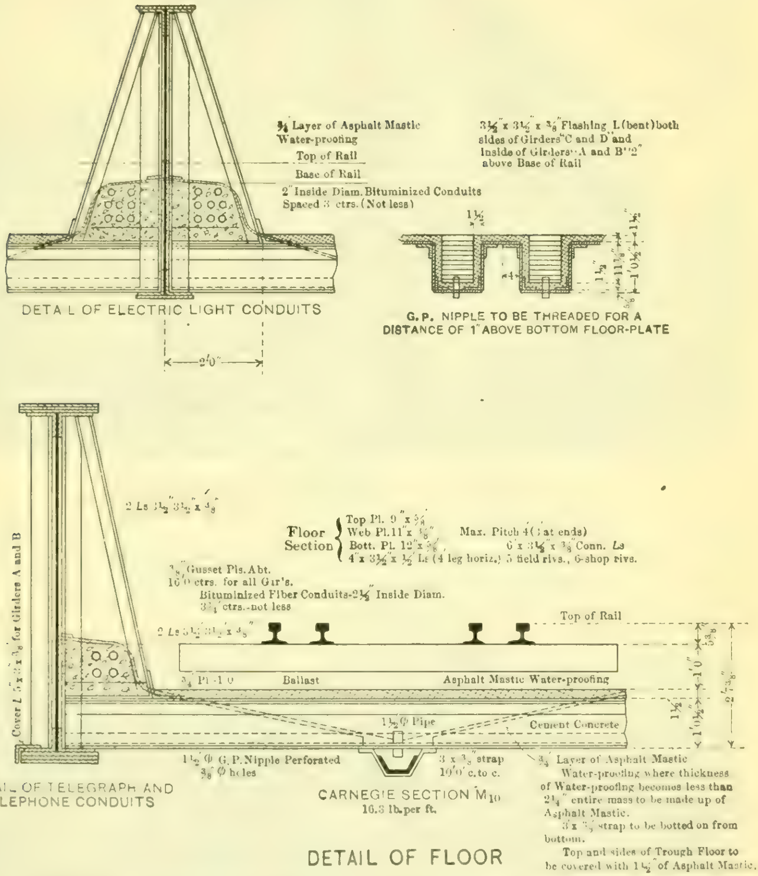


FIG. 10.—WATER-PROOFING BRIDGES: FORMS FOR MASTIC.

FIG. 11.—WATER-PROOFING BRIDGES, SUSQUEHANNA AVENUE.

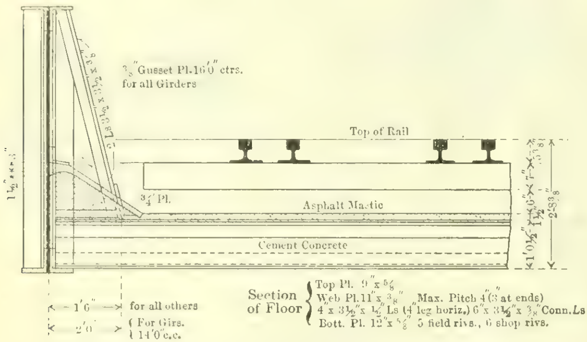


TYPICAL CROSS-SECTIONS OF WATER-PROOFING WHERE IT WAS IMPOSSIBLE TO TAKE CARE OF DRAINAGE OFF THE ENDS OF THE BRIDGE.

FIG. 12.

cost per square foot for all water-proofing work and drainage as follows:

	Cost per square foot.
Special deep floors with nipples; 1.5 in. of asphalt......	$0.42 to $0.55
Hydrex felt on deck bridges; five layers and brick......	0.25 to 0.26
Viaduct; 6-in. Z floor; 1.5 in. of mastic..............	0.24
Standard trough floor, filled with concrete; 1.5 in. of asphalt	0.24 to 0.30



TYPICAL CROSS-SECTION OF WATER-PROOFING WHERE THE DRAINAGE IS TAKEN OFF THE ENDS OF THE BRIDGE. THE TROUGHS FILLED WITH CONCRETE.

Fig. 13.

The specifications for this work may be briefly abstracted as follows:

"Wherever called for on the plans, the decks of the bridges shall be protected as follows:

"First.—By placing 1:3:6 concrete, ¾-in. stone or gravel, troweled on top, as shown on the plans. The cement concrete thus placed shall be allowed to dry thoroughly so as to prevent the formation of steam when the asphalt mastic is applied. All vertical surfaces of concrete or steel shall be prepared by first painting with the asphalt hereafter described, melted and diluted with 62° Baumé naphtha to the proper consistency. The paint shall not be applied to horizontal surfaces except where specially directed.

"Second.—The cement concrete thus prepared shall be water-proofed with asphalt mastic equal in quality, for the intended pur-

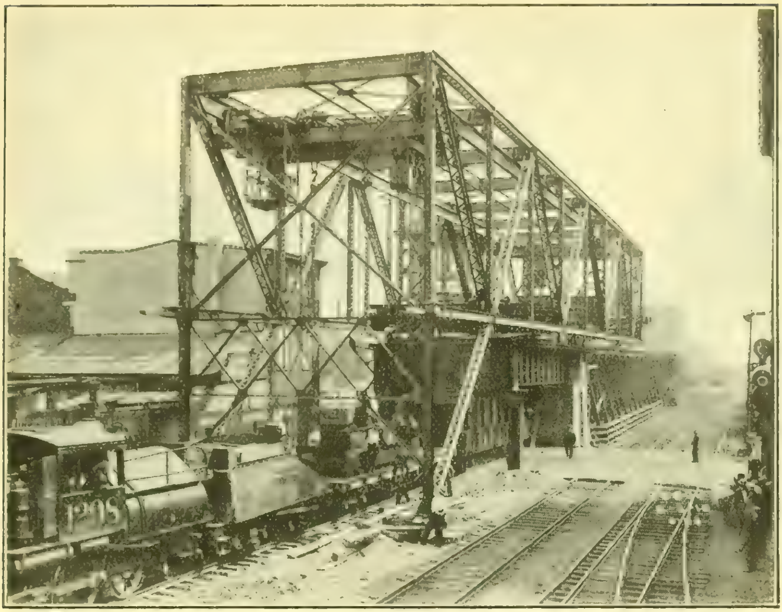


FIG. 14.—TRAVELER STARTING ERECTION OF VIADUCT.

FIG. 15.—EAST HALF OF VIADUCT COMPLETED.

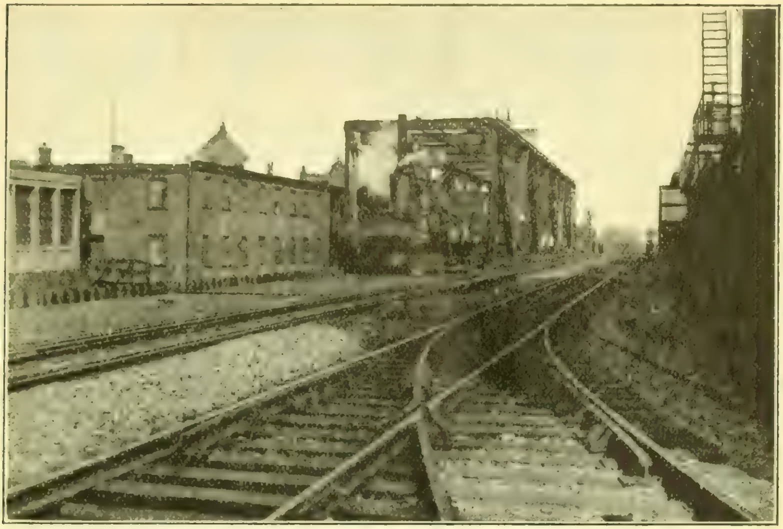


FIG. 16.—ERECTING WEST HALF OF VIADUCT.

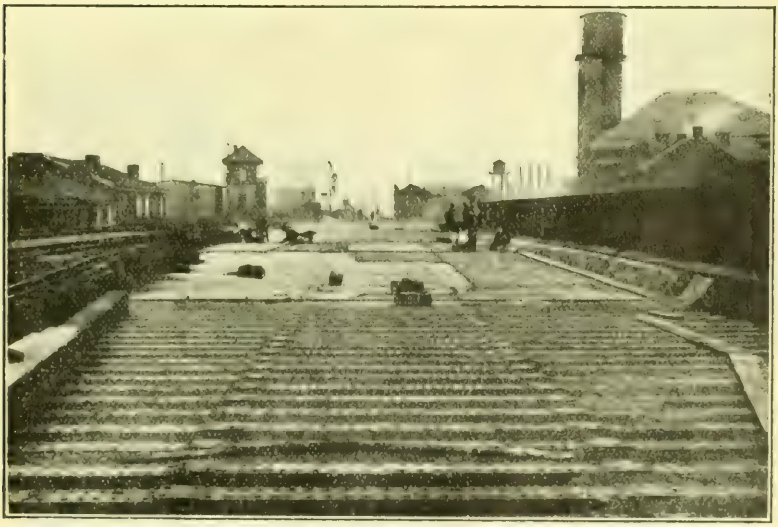


FIG. 17.—WATER-PROOFING SOUTH END OF VIADUCT.

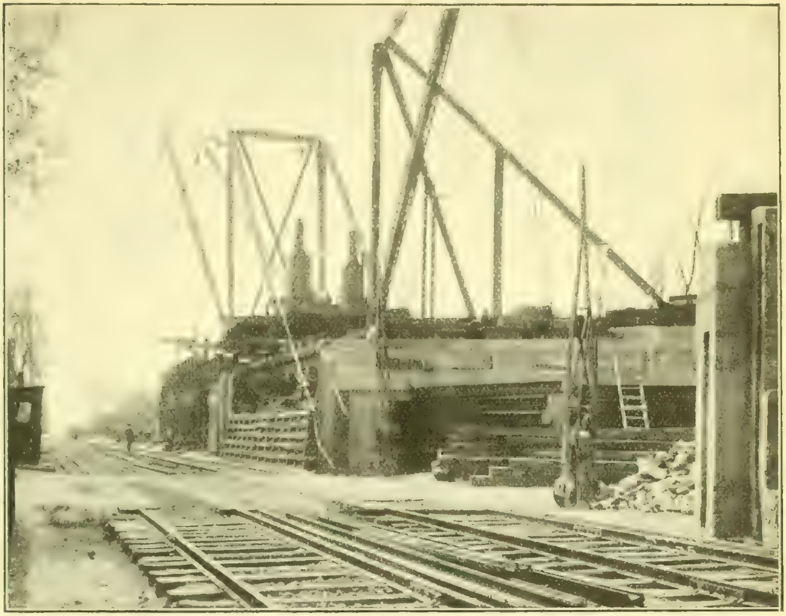
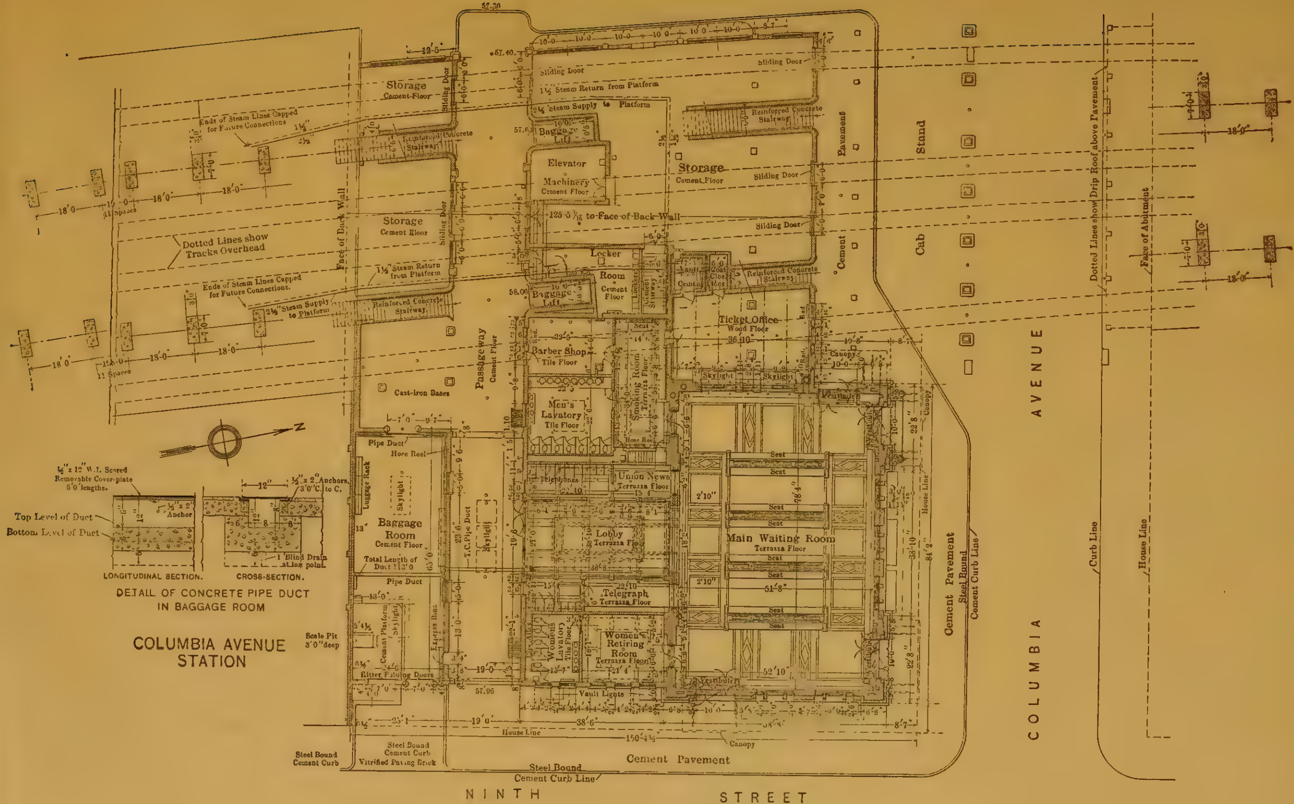


FIG. 18.—ERECTING BRIDGES, TIOGA SECTION, WEST SIDE.

FIG. 19.—WATER-PROOFING BRIDGES, TIOGA SECTION.



FIRST-FLOOR PLAN

pose, as to ingredients used and resistence to water, to the following specifications, and be approved as such:

"Neufchatel, Seyssel, or Sicilian rock mastic...	60	parts.
"Clean sharp grit and sand to pass a sieve of 8 meshes per inch........................	30	"
"Refined Bermudez or Trinidad asphalt........	10	"

"These proportions shall be varied where required by special conditions on the work.

"The mixture shall be made at the site of the work, and heated to a temperature of from 250 to 300° Fahr., and stirred until all the ingredients are thoroughly incorporated. It shall then be spread and thoroughly worked, to free it from voids, and ironed to a smooth surface with hot smoothing irons, if so directed. All mastic shall be applied to the work in two coats, making the total thickness shown on the plans. The coats shall break joints, and the mastic shall be distributed evenly. Where the thickness of the water-proofing materials is less than 2.25 in., the full thickness shall be made up of asphalt mastic.

"Great care shall be taken around expansion joints, drain pipes, and other similar places, and the methods to be followed shall be as specified on the plans or as directed by the Chief Engineer.

"The cost of the water-proofing specified herein shall be included in the lump-sum prices for the bridges."

The asphalt mastic used on this work was prepared from Sicilian Natural Rock Mastic, which averaged from 13 to 16% of bitumen soluble in carbon bisulphide.

Passenger Stations.

Four passenger stations required rebuilding on account of the elevation of the tracks, namely, Girard Avenue Central, Columbia Avenue, Tioga, and Nicetown. As all have been built considerably larger than the old stations, the greater part of the cost has been borne by the Railway Company, the City simply paying one-half of what it would have cost to raise to the new track level structures with the accommodations of those existing at the time the work was started.

Girard Avenue Central.—The four-track viaduct, with its straight alignment at this point, made it possible to provide platforms only on the two outside or local tracks, the station buildings on each side being erected on a steel structure over the bed of Girard Avenue supported by columns on the curb lines. The lengths of the platforms at this point are controlled by existing industrial sidings, and, un-

fortunately, are not as long as desired. This station had very deep foundations for the columns, they being in the bed of an old creek, and cost $54 602.40, the entire cost being assumed by the Railway Company, as the old building was very small.

Columbia Avenue.—This station is an important one, as all trains on the main line and to New York stop there. The tracks cross the street at about the elevation of the old street, making a very severe change of grade. A number of studies were made for the new station, involving very different schemes, all of which, however, included the spreading of the tracks so as to place island platforms between the north- and south-bound tracks, and in so doing entailed the purchase of additional right of way. It was finally decided to purchase a lot at the southwest corner of Ninth and Columbia Avenues, and place on it the main waiting- and baggage-rooms, locating the other necessary facilities beneath the tracks, which are carried on a steel structure for this purpose.

The main building has a frontage of 170 ft. on the south side of Columbia Avenue, 150 ft. on the west side of Ninth Street, and 150 ft. on the east side of Hutchinson Street. The exterior walls are of gray brick with granite base, and Indiana limestone and terra cotta trimmings. The passageway to the trains and the stairways to the elevated platforms are lined with white enameled brick. The interior is designed with complete accommodations for handling heavy traffic. The main waiting-room is 52 ft. by 79 ft., and is 35 ft. high, with polished Italian marble wainscot 9 ft. high. The floors are of marble terraza with marble panels. A ticket office, smoking-room, men's toilet, barber shop, women's waiting-room, telegraph and telephone service, news stands, baggage- and express-rooms, are also provided.

The two platforms on the high level are 800 ft. long. They are of concrete with concrete curbs on the earth-filled portion and with concrete curbs with asphalt mastic over the steel portion. They are covered with heavy sheds of the umbrella type. The entrance stairways to the platforms are from a passageway at right angles to and beneath the track, and between the main waiting-room and the baggage-room. This passageway can be reached from the main waiting-room or from either Ninth or Hutchinson Streets directly. There are exit stairways from each platform, with turnstiles. These lead to Columbia Avenue and also to Oxford Street.

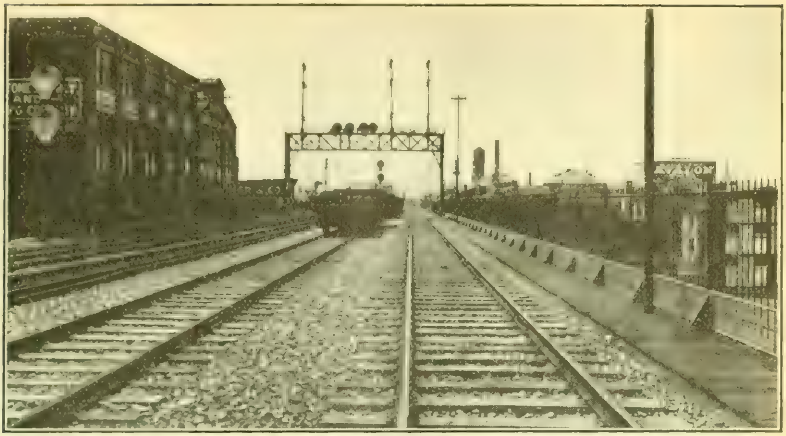


FIG. 20.—COMPLETED VIADUCT FROM ABOVE.

FIG. 21.—OLD STONE TIES, P., G. & N. R. R., IN PLACE.

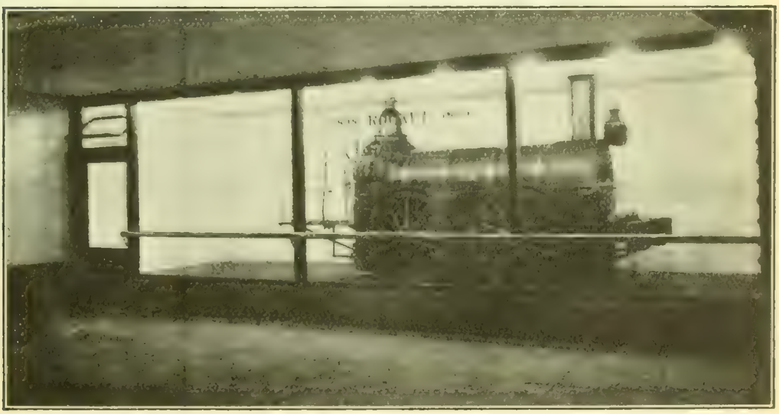


FIG. 22.—ENGINE "ROCKET" IN COLUMBIA AVENUE STATION.

FIG. 23.—COLUMBIA AVENUE STATION.

FIG. 24.—INTERIOR VIEW, COLUMBIA AVENUE STATION.

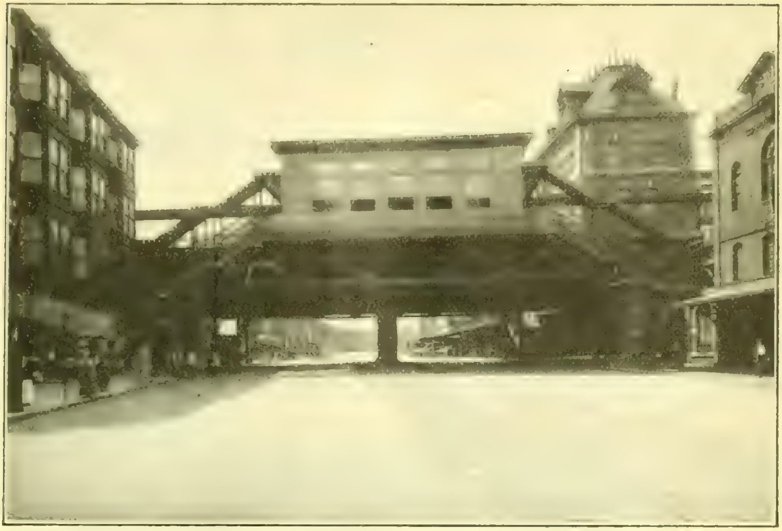
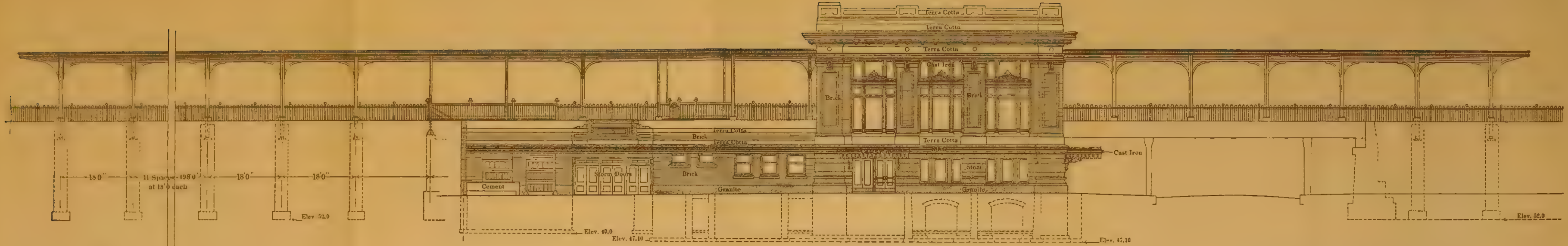


FIG. 25.—GIRARD AVENUE STATION.

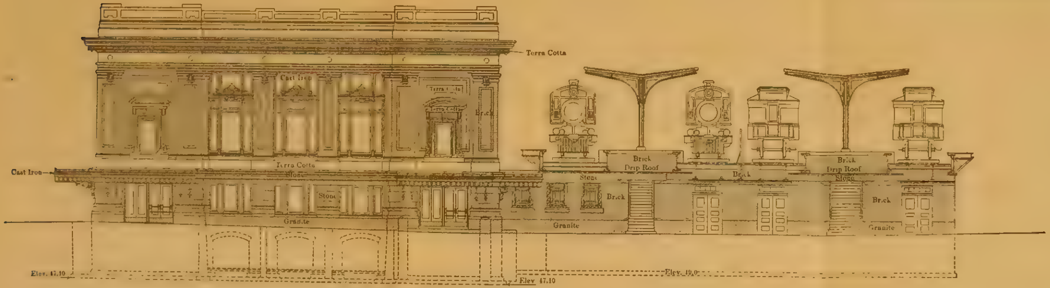
FIG. 26.—TIOGA STATION.

PLATE LX.
PAPERS, AM. SOC. C. E.
MAY, 1913.
WAGNER ON
TRACK ELEVATION, PHILADELPHIA, PA.

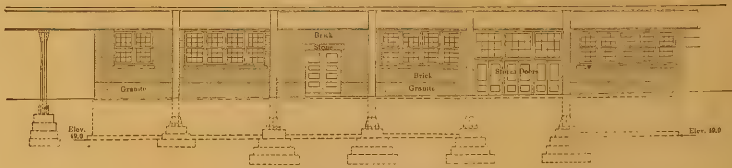


NINTH STREET ELEVATION

COLUMBIA AVENUE STATION



COLUMBIA AVENUE ELEVATION



HUTCHINSON STREET ELEVATION

There are two baggage elevators on each platform, and they are located so as to be accessible from the passageway previously referred to. They are of the hydraulic-plunger type, the pumps being operated by a 20-h.p. electric motor. The cars are 5 ft. 10 in. by 15 ft. 9 in., and the vertical lift is about 17 ft. 6 in. Each elevator has a capacity of 4 000 lb. in addition to its own weight, and travels at the rate of 100 ft. per min., with an average load of 2 500 lb. and with a maintained water pressure of 160 lb.

On the abandonment of the old station, a temporary building was erected on the street level at Oxford Street. This was used while travel was on the low level, and also when it was on the high level on the east side. Access to it at this stage was maintained by a stairway from Oxford Street and a temporary baggage lift between Oxford Street and Columbia Avenue. On the completion of the main waiting- and baggage-rooms, the temporary buildings were removed, and all travel was handled from the east platform until all four tracks were placed in service. The cost of the station building, platforms, shelters, etc., was $217 134.15.

Engine "Rocket".—Facing on the passageway to the trains, in the Columbia Avenue Station, there is an inclosed room, electrically lighted, in which the Engine "Rocket" rests on the original stone ties, cast-iron chairs, and wrought-iron rails which were recovered from the excavations made along the line of the elevated work, and which constituted the original roadbed of the Philadelphia, Germantown, and Norristown Railroad. A large number of the ties were found, a few of the chairs, and only a small quantity of the rails.

The "Rocket" was one of a number ordered by the Philadelphia and Reading Railroad in 1836 from Braithwaite and Millner, of London, England, and was built in 1838. It was delivered at the Port of Philadelphia, and conveyed by canal to the foot of Penn Street, Reading. From this point, it was hauled on its own wheels, through the streets, by horses, and placed on the tracks of the Philadelphia and Reading Railroad at Seventh and Penn Streets, Reading. The railroad was completed at that time between Reading and Norristown. It was placed in passenger service in May, 1838, and was retired in March, 1879, having run 310 164 miles. It was placed on exhibition at the World's Fair at Chicago in 1893, and also at the St. Louis Exposition in 1904. It weighs 8.4 tons.

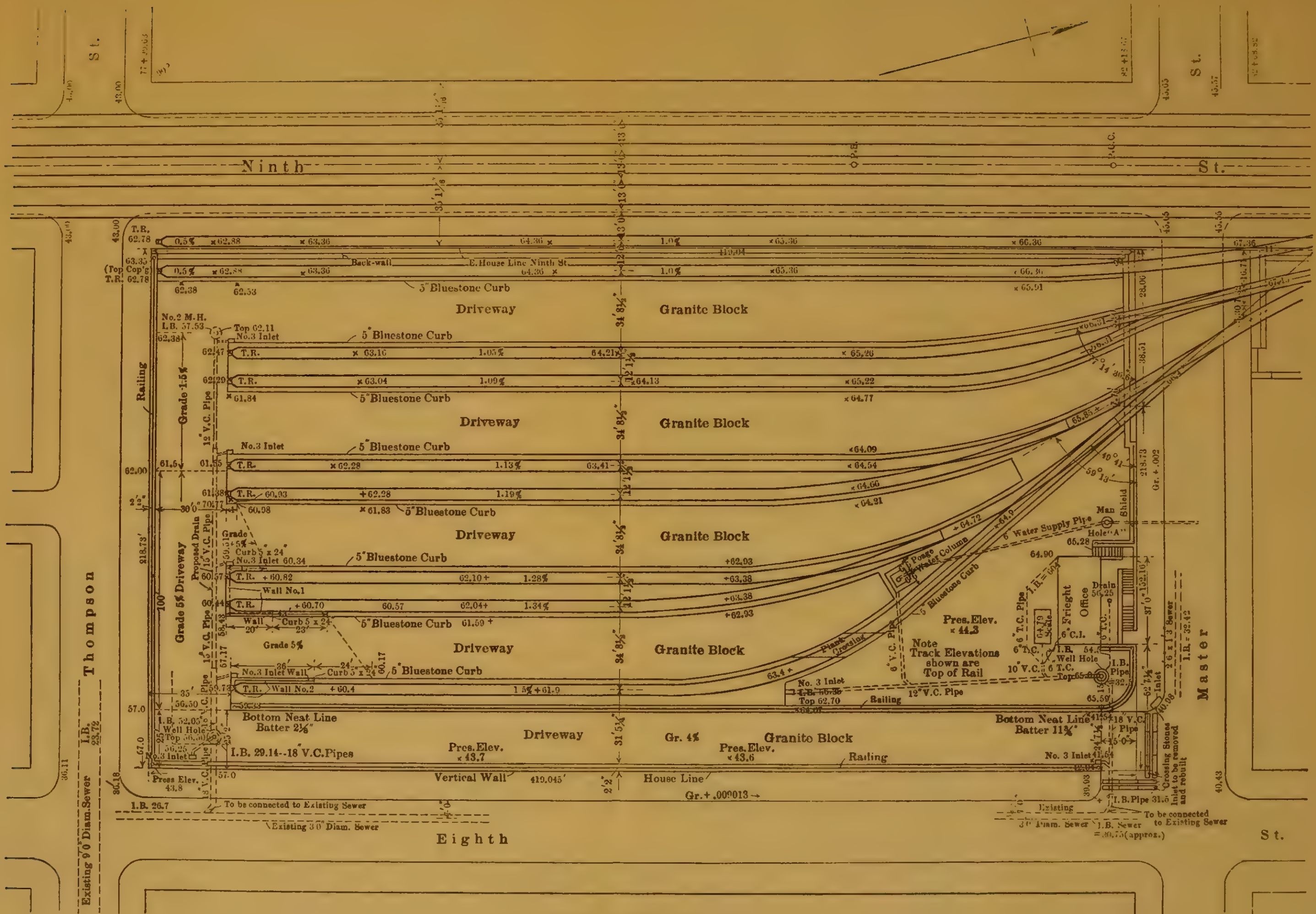
Tioga and Nicetown.—These two stations may be referred to together, as they are in many respects similar. They are in a semi-suburban section of the City, and are used only for local passenger business. They are one-story buildings above the track level, with an additional story on the street level. The larger station at each point is on the south-bound side, in which is also the ticket office. They are built of brick with terra cotta trimmings, and are neatly finished throughout. The platforms can be reached by several flights of steps or by paths through the station grounds. Electric lifts are provided on both sides of the tracks for baggage and express service, and tunnels connect the north- and south-bound stations beneath the tracks. The elevators have a lifting capacity of 2 000 lb. at a speed of 50 ft. per min. The dimensions of the cars are 5 ft. by 10 ft.

The new station at Tioga, including the grading of the grounds, the cement platforms, and the driveways, cost $62 886.64. That at Nicetown, with similar appurtenances, cost $43 554.57.

While the two tracks on the west side were being elevated, the station buildings on this side were being erected, and when travel was placed on that side, a temporary platform was erected to care for the north-bound business, while the two tracks on the east side and the north-bound station were being completed.

Freight and Car Cleaning Yards.

The Railway Company operated freight yards at Eighth and Master, Tenth and Berks, and Broad and Lehigh Streets, before the elevated work was started, as well as car cleaning yards at Twelfth and York and Thirteenth and Lehigh Streets. The finished general plans provided for the retention of the first two freight yards and the rearrangement of the other so as to consolidate the car cleaning yards at Broad and Lehigh Streets. The yards between York and Cumberland Streets were designed for freight purposes. All were designed as elevated yards except that for the car cleaning, in which there was but slight change in grade. A number of studies were made to determine the best and most economical method of arranging the grades of the tracks in these yards, as well as the grades of the driveway approaches; and the final plans, it is believed, embody the most economical arrangement that could be made. The yards in all cases were thrown entirely out of service during construction. Concrete walls were built on the



MASTER STREET YARD
GENERAL PLAN

street lines, the embankments placed to the new level, and all driveways provided with 5-in. bluestone curbs, and paved with granite blocks on a sand base. As a general rule, all ramp driveways leading to the streets had 4% grades, and the maximum grade on the tracks was 3 per cent. All track work was done by Company forces on emergency orders. The contracts for the freight yards were as follows, and show all the cost except the track work:

Location.	Total cost.	Car capacity.
Master Street	$97 868.30	66
Berks Street	70 350.03	55
York Street Yards	67 059.23	104

Car Cleaning Yard.—This yard has a capacity of 230 passenger cars, and is provided with a service building, a small car repair and paint shop, a power-house building for furnishing steam, air, and lighting, and the yard is equipped with complete piping for the delivery of steam, air, and water to any point. All pipes are placed in creosoted wooden conduits, readily accessible for necessary repairs. The mechanical equipment of the power-house was furnished by the Motive Power Department, and its cost is not included. The entire cost, exclusive of the track work and the mechanical equipment, was $53 326.82.

Green Street Engine Yard.

Practically all the engines operating in the Reading Terminal are cared for in the Green Street Yard. The four main tracks and a track for the delivery of coal to the coaling station run through this yard on an elevated structure of concrete walls and fill. Engines coming from the Terminal run north to about Brown Street and back down a 3% grade on the east side of the yard to the original level beneath the coaling station, where they receive coal, water, and sand and dump ashes. They then run south, turning if necessary on a 75-ft. turn-table operated by an electric motor, and pass through a tunnel beneath the main tracks to the west side of the yard where they can proceed to the engine-houses for repairs and cleaning, or up a second 3% grade to the high-level storage yard from which they run out on the main tracks and back to the Terminal. Thus all crossing of the main tracks is avoided. There are two turn-tables on the west side of the yard. This arrangement makes four bridges over Fairmount Avenue at different levels. Beginning on the west side, one track for engines leaving

the yard; four main tracks; one coaling track for the coaling station; and one track for engines entering the yard. This arrangement made it unnecessary to raise the whole of the yard, with the engine-houses and turn-table on the west side, to the new elevation, and thus effected a material saving in the cost of the work.

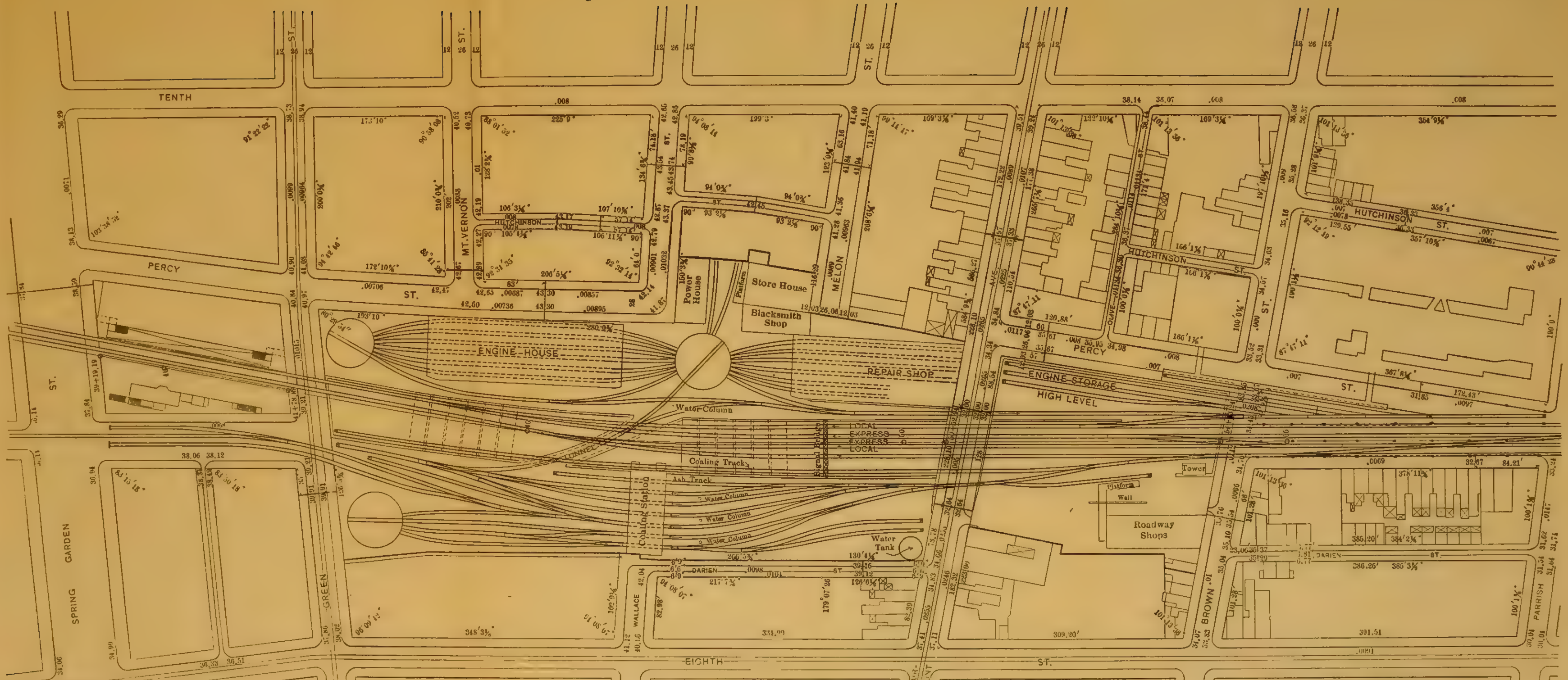
Coal-Pocket Yards.

The Railway Company owns and leases several large coal yards, one on the east side of the tracks between Berks and Norris Streets, and one on the west side at Tenth and Norris Streets. Only the first will be described, the other being similar but smaller.

Originally, the tracks in the yards were about 15 ft. above the street level. Due to the elevation of the main tracks, the difference in level was increased to about 41 ft., and it was decided to construct pocket yards, on account of the great height. There are two double-track pockets, parallel to the main tracks, each with a capacity of 10 000 tons in the pockets. Each is about 46 ft. wide and 500 ft. long. The two pockets are separated by a driveway about 37 ft. wide. The bottoms of the pockets are about 10 ft. above the paved surface of the yards, thus allowing delivery teams to be driven under them and loaded through chutes.

The type of construction was determined only after very careful study. Designs were made for all steel, reinforced concrete, and all wood, and the costs were carefully estimated; a number of different combinations were also tried. It was found, finally, that the composite design finally constructed was cheaper, both in first and capitalized cost, than either all steel or reinforced concrete, and as cheap in first cost as all wood. It consists essentially of a covered double-track steel plate-girder viaduct, wooden longitudinal pocket walls, and wooden pocket floors, supported on vertical concrete transverse partition walls of full height, without reinforcement. Each complete pocket is divided into 20 panels by the concrete walls, which are placed at 25-ft. centers. These walls are 46 ft. long, about 3.5 ft. thick at the base, where they rest on footings of reinforced concrete 4 ft. deep, 10 ft. wide, and about 49 ft. long.

Coal is delivered to the pockets by standard-gauge cars on each side of the longitudinal partition, each track being supported by two lines of 30-in. steel plate girders, at 5-ft. centers. The tracks are enclosed by a monitor of frame and corrugated iron with a slag roof.



GREEN STREET YARD
GENERAL ARRANGEMENT

to be dumped into hoppers and raised into the pocket. The pockets to be twelve in number, two over each coaling track. The combined storage to be 2 000 tons. Each pocket to be provided with approved chutes, and with steam pipes and valves to thaw the coal when frozen. Ash pits to be arranged so as to enable engines to coal and dump ashes at the same time, and be supplied with water for quenching the ashes. Provision to be made for pockets for storing 250 cu. yd. of ashes. Hoppers with a storage of 8 cu. yd. of dry sand delivered from the high-level coaling track, and the necessary piping to transport the sand by air pressure to the delivery pockets, each of 4 cu. yd. capacity, one over each coaling track.

Machinery.—Duplicate machinery to be provided throughout, and designed for economy in operation and maintenance; also, to be as noiseless as possible. Each coal-handling unit to have a guaranteed capacity of 100 tons per hour. Machinery for handling ashes to have a capacity of 250 cu. yd. in 10 hours from the six coaling tracks.

Power.—All power to be electricity, which will be brought to the building by the Railway Company from a power-house on the west side of the yard.

A number of bids were received, based on different methods of handling both coal and ashes, and the contract was finally awarded to the Link Belt Company. The total cost of the work was $96 670.13. The principal items entering into this cost were as follows:

Building, drainage, etc.	$48 090
Coal-handling machinery	22 200
Ashes-handling machinery	8 590
Sand-handling machinery	2 270

The proposals required the bidders to name the following estimated figures, which in the accepted bid were as follows:

Cost of handling coal from cars to locomotive, based on 700 tons in 10 hours	$0.0225 per ton.
Repairs and maintenance on coal-handling machinery	0.007 " "
Cost of handling ashes from pits to cars, based on 250 cu. yd. per 10 hours	0.059 " cu. yd.
Repairs and maintenance, ashes-handling machinery	0.012 " " "

The general arrangement of the plant is shown on Plate LXIII.

FIG. 27.—CUMBERLAND STREET BEFORE WORK WAS STARTED.

FIG. 28.—CUMBERLAND STREET AFTER WORK WAS COMPLETED.

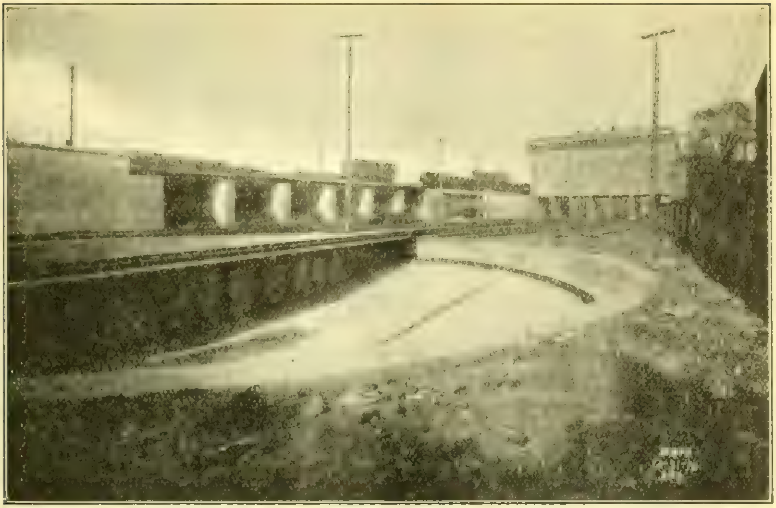


Fig. 29.—Coaling Station; and East Side of Green Street Yard.

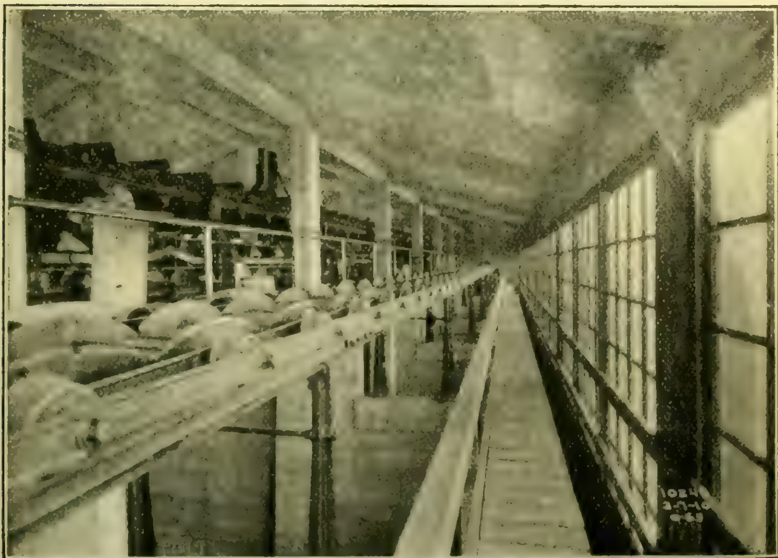
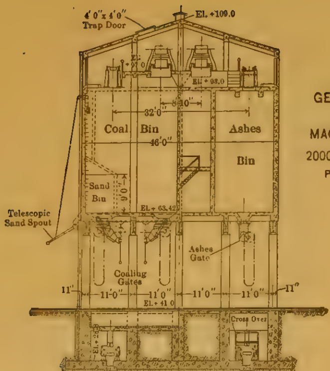


Fig. 30.—Machinery Floor, Interior of Coaling Station.

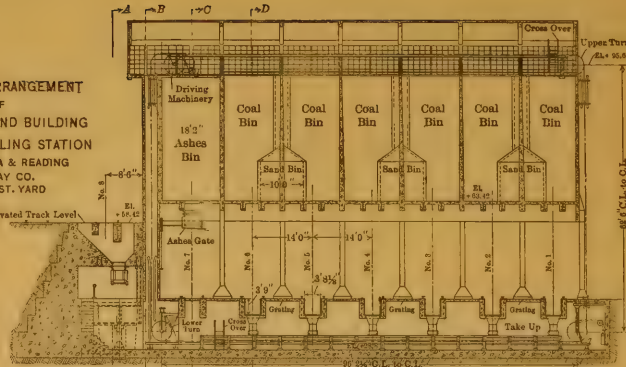
GENERAL ARRANGEMENT OF MACHINERY AND BUILDING

2000-TON COALING STATION

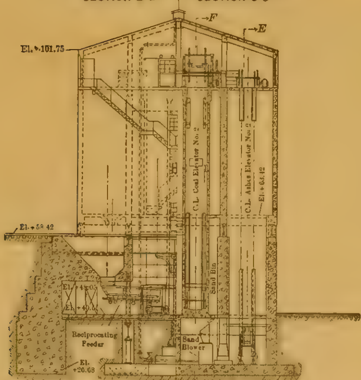
PHILADELPHIA & READING RAILWAY CO.
GREEN ST. YARD



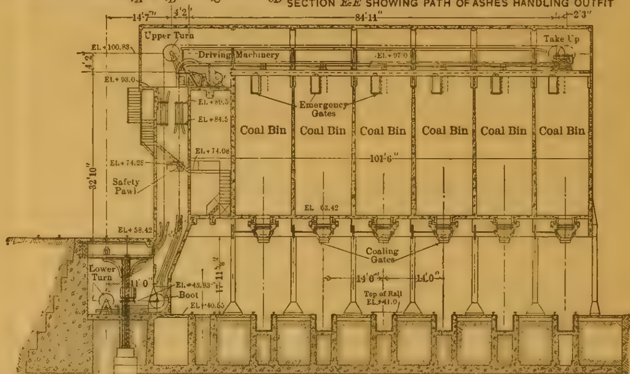
SECTION D-D SECTION C-C



SECTION E-E SHOWING PATH OF ASHES HANDLING OUTFIT



ELEVATION & SECTION A-A. SECTION B-B.



SECTION F-F SHOWING PATH OF COAL HANDLING OUTFIT

The coal-handling machinery consisted of reciprocating feeders to two Link Belt, gravity-discharge, combined elevators and conveyors. On the horizontal runs the roller chains travel on steel tracks placed on the conveying runs so as to suspend the buckets above the cast-iron trough along which the coal is conveyed. Each machine has a chain speed of 75 ft. per min., and is actuated by a 25-h.p. General Electric motor, the motive power being located in the machinery room.

The fire-boxes of engines are cleaned into concrete brick-lined pits, and scraped through funnel-shaped cast-iron hoppers, with duplex gates and operating valves, to duplex-pivoted overlapping bucket carriers following rectangular paths and discharging into the storage pockets. These buckets are overlapping and of malleable iron, pivotly secured to two strands of heavy malleable-iron roller chain.

Dry sand is delivered from the receiving hopper, through pipes with reinforced bends, under an air pressure of 70 lb. Special chutes lead from the delivery hoppers to the engines, supplying sand by gravity.

The entire foundation of the pockets is of reinforced concrete, and this material is used for the construction above the floor of the pockets, and is properly designed according to the requirements of the Bureau of Building Inspection, City of Philadelphia. The drainage is arranged so as to lead directly to the city sewers.

The high-level delivery track is constructed on a 1% grade, the station being located midway in its length, so that ten loaded coal cars can be placed at the upper end of the grade, dropped by gravity to the hoppers, there unloaded, and dropped out of the way, without reaching the main tracks.

Permanent Tracks.

The main running tracks, previous to starting work, were laid with rails of 90-lb. Am. Soc. C. E. Section, the side tracks and yards with lighter and varying sections. A complete survey and joint inventory was made of all the existing track materials, by representatives of the City and the Railway Company, before the work was started. This was for the purpose of eventually determining the respective shares of each in the cost of the permanent tracks, as the number of tracks on the completed work was in excess of the original number, and in many cases the new tracks were laid with heavier rails and fittings. The City only joined in the cost of replacing the original weight, all

excess being a betterment to the Railway Company and paid for entirely by them. All track details were furnished according to the standard plans and specifications of the Railway Company.

The most interesting details of these specifications are given herewith:

Rails.—90-lb. Am. Soc. C. E. Section. Shrinkage, 6.5 in. in 33 ft. Chemical composition:

Carbon .... 0.55 to 0.65%, averaging 0.58%
Phosphorus .... not to exceed 0.075%
Silicon .... not to exceed 0.20%
Manganese.....0.90 to 1.15%, with average above 1.00%

Drop test: 3 ft. between centers of supports; tup, 2 000 lb.; anvil block, 20 000 lb.; striking face of tup, not more than 5 in.; height of drop, 18 ft.

Ties.—First-class ties of white or rock oak. Dimensions, 8 ft. 6 in. long, 7 in. thick, and not less than 7 in. nor more than 14 in. on the narrowest face.

Ballast.—Good, hard, durable, broken trap rock, crushed so that it will not be larger than will pass through a 2.5-in. ring.

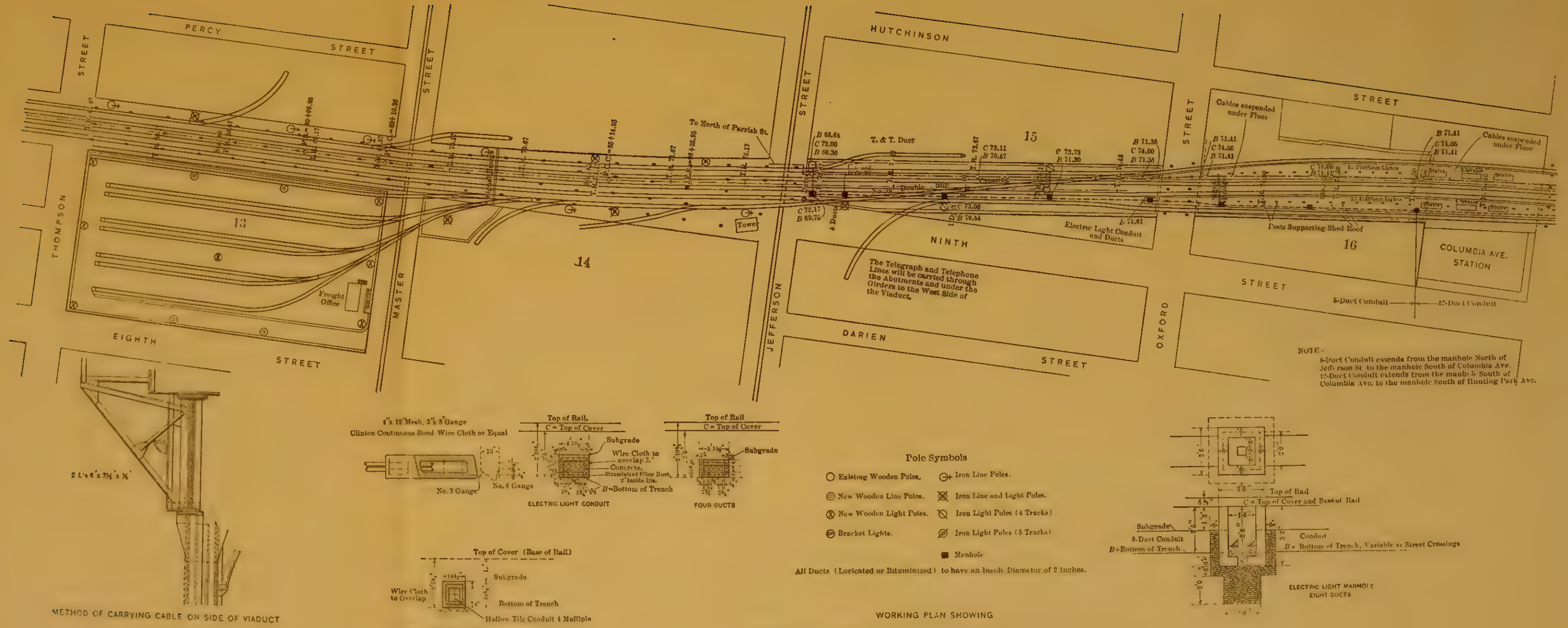
Specials.—100% joint-plates; Verona nut-locks; hard-steel, centered frogs; Wharton, guard-rail clamps; Ramapo or Pennsylvania Steel Company, switch stands; O'Brien, insulated joints.

Temporary Signals.

During the changes in the tracks, temporary block signals were erected and maintained throughout the entire length of the line, using old material, as far as possible, and adapting it temporarily to the new conditions. Where lead-outs to the important yards were maintained, or where it was necessary to pass from a two-track to a four-track condition, temporary towers were erected and connected with the necessary switches and signals with manual interlocking. All this was done by Company forces, on emergency orders covering the temporary track work, thus keeping the operation of trains at all times under the control of the Operating Department, and avoiding all possibility of interference with the safe movement of trains.

Permanent Signals.

Before the work of elevation was started, the entire line was equipped with Hall automatic block signals, and two small manual



WORKING PLAN SHOWING
PERMANENT ELECTRIC LIGHT AND TELEGRAPH AND TELEPHONE LINES.

interlocking plants were located at Fairmount Avenue and Huntingdon Street, respectively, to control the shifting into the yards at these points. After the elevated track plans were completed, it was decided to operate all the switches between Broad and Green Streets affecting the four main tracks from electro-pneumatic interlocking plants, aggregating 98 working levers. These are as follows:

Cumberland Street	11	working levers.
Tenth Street	39	" "
Jefferson Street	21	" "
Brown Street	27	" "
	98	working levers.

The new signaling apparatus was put in by the Union Switch and Signal Company, and embodied the latest practice, such as the following:

1. The auxiliary control of all signals by all switches by means of the duplications of positions of both switches and signals with relays;
2. Approach and route locking;
3. Detector circuits;
4. Federal switch guards.

The high signals are semi-automatic, three-position, lower-quadrant type, with a short "all route" or "call-on" signal beneath, on the same mast. All these signal masts are carried on signal bridges.

The short-arm signal is a two-position signal—horizontal for "stop" and 45° below the horizontal for "caution—proceed." It is used to call trains on past the high signal or signals on the same mast, if, for any reason, the proper high signal cannot be displayed in the "proceed" position, and this "call-on" feature is accomplished by a push-button placed directly under the signal lever. In addition to its "call-on" functions, the short-arm signal governs all the remaining routes, other than the two most important ones controlled by the two high signals above it. The maximum number of high arms on any one mast is two, governing only one route each.

The Federal switch guards are 55 ft. in length, and are placed on every switch, movable-point frog, derail, etc., over the entire territory. The detector circuits are an average of 130 ft. in length.

The route-locking on the various plants is arranged with a releasing feature, whereby all switches in the rear of a train on the route are released as fast as the entire train clears the respective fouling limits of the several switches involved in the route. Thus a route cannot be changed ahead of a train, but may be changed behind one, provided the home signal has been put to the "stop" position. Hand time releases are installed for the release, when necessary, of signal levers affected by the approach locking feature.

Electric lights (incandescent) of $\frac{1}{4}$-c.p. are applied to all switch levers, this being supplementary to the detector circuit locking. Each light is encased in an iron box with a separate iron cover in which there is a frosted-glass disc. This iron box is directly under the levers, and is at all times in view of the signalman. These indicating lights are normally lighted up, illuminating the small white frosted-glass disc with number thereon corresponding to its respective switch lever number, thus showing the signalman that there is no train on the track circuit governing the switch, and the lever is free to be thrown. The extinction of the light indicates the presence of a train on the switch, and that lever is locked and cannot be thrown.

Approach and home indicators are provided in the tower. The approach indicator is of the disc type, and the home indicator, indicating from the home signal entirely through the interlocking, is of the semaphore type.

The semi-automatic high semaphore signals at the entrance to the interlocking provide the signal aspect for automatic indication through the interlocking block, that is, these signals will assume the "proceed—caution" (45°) position when the interlocking block is unoccupied, and when the track and switches are right for the route governed, and when the signalman throws the signal lever, that is, these signals will go on from the "caution" to the "proceed full speed" (90°) position, if conditions are right for two blocks ahead. They will go automatically to the stop position, after the train has passed them and entered the interlocking block.

The automatic signal aspect at the end of the interlocking block—governing the territory between and up to the next interlocking plant—is a double-head "home" and "distant," normal danger, Hall disc signal. These disc signals are wired in conjunction with the semi-automatic semaphore signals, so that, in all cases, for all kinds of signals, the

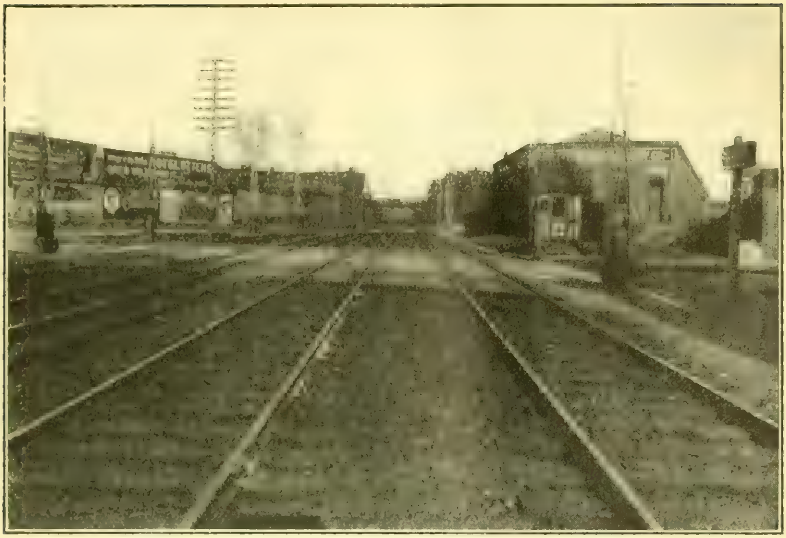


FIG. 31.—WESTMORELAND AND NINETEENTH STREETS BEFORE WORK WAS STARTED.

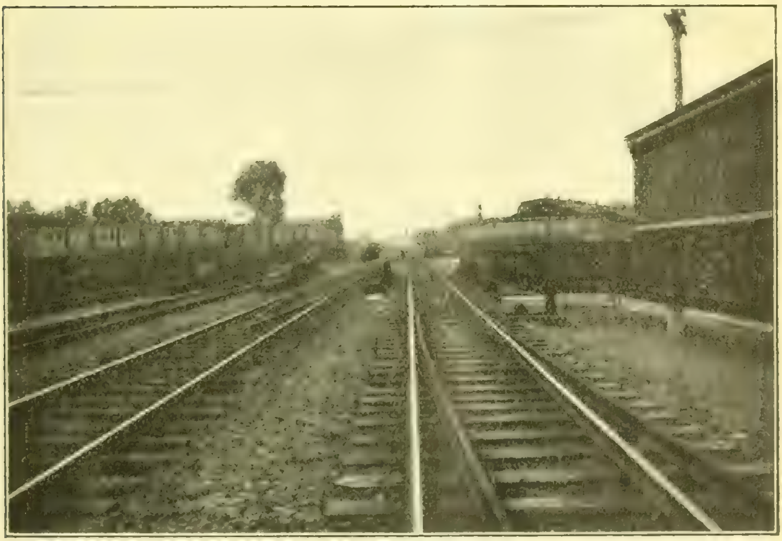


FIG. 32.—WESTMORELAND AND NINETEENTH STREETS AFTER WORK WAS COMPLETED.

proper home and distant indications are given, and also so that the disc signals through the interlocking will only clear if the proper route, leading to them, is set up.

At Broad Street the new signaling connects up with three-position semi-automatic signals, and with home and distant disc signals, as above explained. The signaling at the Green Street end joins up with two-position normal clear automatic pneumatic semaphore home and distant signals, governing into the Reading Terminal.

Eight iron signal bridges on the elevated carry the signal masts for the high semi-automatic semaphore signals, short-arm signals, and side signals. Table 7 gives the location, number of tracks crossed, and cost of same. At Columbia Avenue Station, where the tracks spread apart on account of the station platforms, there is a two-track signal bridge north of the station carrying signals for the south-bound tracks, and a two-track bridge south of the station with the signals for the north-bound movement. In all cases the clearance from underside of signal bridge to top of rail is 23 ft. 8 in.; and the side clearance from leg of bridge to center line of nearest track is an average of 7 ft.

Throughout the entire territory, between Broad and Green Streets, all switches are interlocked and controlled by machine.

TABLE 7.

Contract No.	Location.	Number of tracks.	Cost.
47	South of Fairmount Avenue	5	$1 684
	North of Poplar Street	4	1 558
	North of Master Street	4	1 441
	North of Oxford Street—two bridges	4	1 489
	North of Columbia Avenue	5	1 595
33	North of Norris Street	8	1 503
	Twelfth and York Streets	5	1 100
	Thirteenth and Cumberland Streets	5	1 174

Power plants, at Huntingdon and Wallace Streets, supply the compressed air (100 lb. per sq. in. at the power-house) to the towers through a 2-in. main air pipe, which is buried 6 in. in the ballast alongside the track. There are reservoirs in the main air pipe for drainage, and also auxiliary reservoirs in the $\frac{3}{4}$-in. branch pipes between the functions operated and the main air pipe.

Electric current is furnished from the power plant at Huntingdon Street at 650 volts and 25 amperes (D. C.) for charging the necessary storage batteries at the various interlocking towers.

The charging wire, etc., and all signal wires and cables, are laid in trunking on top, at the side, and between the tracks of the elevated structure. There is a main switch-board and rheostat at the power house at Huntingdon Street controlling the current for the charging of the storage batteries, and also a switch-board at each plant for the control of charging and discharging. These switch-boards at the several plants are wired so that, if desired, all the batteries at all four plants can be charged in a series at one time, or, on the other hand, any battery or batteries desired can be cut off from charge and put on discharge.

Electricity is used for the lighting of all signals, towers, etc. The signal lanterns are specially designed, each containing two 2-c.p. incandescent electric lights, and, for emergency use, an oil fount, wick, etc. The high-tension (1 100 volts, A. C.) wire for the electric lighting is carried in a separate conduit from the trunking used for the signal wires, and this current, by means of transformers on the ground at each signal group, is stepped down and changed to 110 volts (D. C.) for the signal lamps. Separate trunking is also run for these 110-volt wires.

Communication between the towers is provided for by train describer and telephones. These train describers consist of sending and receiving instruments for each track, and the description of traffic is accomplished by the signalman pressing certain numbered buttons (according to code) on the sending instrument for a certain track. This action appears on a corresponding receiving instrument at the next tower, giving full information to this signalman of coming train movement.

The signal tower at Cumberland Street sets back from the center line of the track 10 ft., and is a brick building, three stories from the street—two stories above the elevated structure. It has brick facings and an overhanging tile roof. The inside dimensions are 21 ft. 9 in. by 11 ft. 8 in. The machine is in the top story; on the track level are the relay racks and relays and the storage batteries. On the street level the room is used for the signal maintainer and for the furnace.

The tower at Tenth Street is the largest of the four. It is triangular in plan, with the hypotenuse running parallel with the railroad. The arrangement of the rooms is similar to that at Cumberland Street.

The tower at Jefferson Street is built on the viaduct and back

10 ft. from the center line of the track. It is a copper-sheathed, steel structure, with overhanging tile roof. The inside dimensions are 26 ft. by 11 ft. It is two stories high.

The tower at Brown Street sets back from the center line of the track 9 ft. It is of brick, two stories high, and similar to that at Cumberland Street. The inside dimensions are 25 ft. 10 in. by 11 ft. 3 in. In this tower is placed a temporary six-lever frame machine, with four working levers to take care of the converging of the new four-track line into the old two-track line at Green Street. This will be removed when the four-tracking is completed into the Reading Terminal.

The cost of the signal towers was as follows:

Location.	Cost.
Cumberland Street	$3 990
Tenth Street	5 990
Jefferson Street	4 114
Brown Street	3 760

The entire cost of the interlocking work, exclusive of the signal towers and bridges, was $127 462.90.

Locomotive Water Supply.

On account of the changed conditions in the Green Street Engine Yard, it was necessary to lay new pipe lines, making connections with the existing water tanks on the west side of the yard; furnish and erect three new 12-in. Poage automatic water columns; re-erect an old 8-in. column on the west of the main tracks; and construct the pits and drainage to the city sewers. The total cost of this work was $6 107.27.

Changing Grades of City Streets.

All the plans for the necessary changes to the city streets were prepared by the Bureau of Surveys and approved by the Railway Company. The work was divided into five contracts.

The work under these contracts included the underpinning of the adjoining buildings, where the changes in the streets affected their foundations; the excavation between house lines to the new street level; the renewal and reconstruction of all gas and water mains, electrical conduits, and other underground structures; provision for temporary access to all buildings, and the repaving of driveways and

sidewalks. It also covered the necessary adjustments and repaving of streets, where there was no change of grade, but where the previous existence of the tracks of the railroad and their removal made such adjustments necessary. It also covered the construction of the smaller sewers, the work on which could be deferred until the streets were excavated. The work covered was generally as shown in Table 8.

TABLE 8.

Contract No.	Description.	Cost.
108	Changes of grade, Fairmount Avenue and other adjoining streets; paving Ninth Street from Brown to Jefferson Streets; changes of grade on Columbia Avenue and adjoining streets	$122 833.27
109	Adjustments of streets, Berks to York Streets; changes of grade of Cumberland, Thirteenth and adjoining streets	110 756.42
110	Changes of grade on Allegheny Avenue, Westmoreland, Ontario and adjoining streets affected	134 338.60
111	Changes of grade of Hunting Park Avenue and adjustments of all streets from Tioga Street to Richmond Branch	43 125.00
115	Adjustments on Montgomery Street	2 185.75
	Total	$413 239.04

The principal prices and the quantities of the most important items are given in Table 9.

TABLE 9—PRICES AND QUANTITIES OF PRINCIPAL ITEMS OF STREET CONTRACTS FOR GRADING AND PAVING.

Kind of Work.	Contract No. 108.		Contract No. 109.		Contract No. 110.		Contract No. 111.	
	Rate.	Amount.	Rate.	Amount.	Rate.	Amount.	Rate.	Amount.
Excavation, cubic yards	$0.54	24 050	$0.45	30 547	$0.54	64 125	$0.54	20 918
Rubble underpinning, cubic yards	14.00	44	20.00	358	14.00	1 460	14.00	36
Granite block paving, square yards	3.15	3 676	2.90	2 350	3.15	309	3.15	1 066
Sheet asphalt paving, square yards	1.37	17 281	1.85	9 478	1.37	9 014	1.37	7 144
Cement sidewalk paving, square yards	1.19	12 815	1.25	8 782	1.19	6 329	1.19	3 194
6-in. cement curb, linear feet	0.75	1 097	1.50	3 837	0.75	1 032	0.75	.....
8-in. cement curb, linear feet	0.80	8 940	1.50	3 609	0.80	1 437	0.80	1 959
Granite block repaving, sand base, square yards	0.45	1 964	0.40	1 410	0.45	5 497	0.45	2 324
Granite block paving, 6-in. concrete base, square yards	0.85	2 788	1.15	1 351	0.85	7 528	0.85	12

INDUSTRIAL CONNECTIONS.

Before the work was begun, there were many industrial connections to the existing tracks, leading to coal yards of retail dealers, to factories,

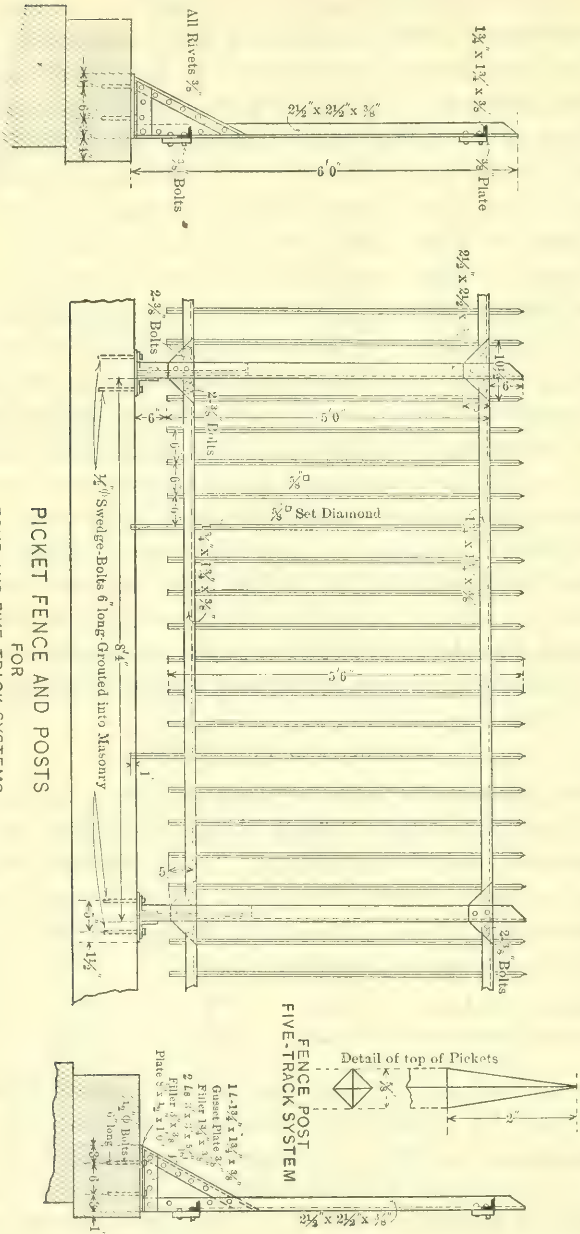
and for general industrial purposes. Under the law, the burden of the reconstruction of these connections falls principally on the owner, as the Railway Company cannot assist in the cost of reconstruction on private property. The cost of making the connections from the main tracks to the right of way was borne jointly by the City and the Railway Company as part of the work of elevation of the tracks, where industrial connections formerly existed. Owing to the requirements of the safety appliance clauses of the Interstate Commerce Commission, the Railway Company established a minimum radius of 150 ft. for the new connections, and, further, decided on a minimum length of siding to accommodate two cars. The radii of many of the former sidings was as small as 50 ft., in many cases requiring the insertion of special extra links between cars in operating, and even then attended by frequent derailments. In minimum cases, in the new work, a No. 4 curved frog was used, and, with the minimum radius, this made it possible to maintain many connections where the frontage on the railroad was small. However, the more important connections have been maintained, although suits are pending where the new conditions have made their continuance impossible. Where coal yard sidings have been reconnected, the additional height has made it possible for the owners in many cases to build pockets and load directly into wagons without extra handling.

Railings and Picket Fence.

Careful studies were made for the design of railings to be placed along the retaining walls, and finally the gas-pipe railing with cast-iron posts shown in Fig. 33 was adopted. The specifications for the pipe required that it be dipped at the shops in red lead paint containing 95% of red oxide of lead. The cost of this type of railing, including the attachment to the walls, was as follows:

Contract numbers...	5	7	14	32
Cost per linear foot..	$0.58	$0.75	$0.58	$0.68

After the work was well under way, the management of the Railway Company decided to enclose its property throughout, so as to prevent trespassing, and plans were prepared for a picket fence, designed so as to make it very difficult to scale and at the same time be as economical as possible. Gates of the same type were also required at all the industrial connections.



FENCE POST FOUR-TRACK SYSTEM

FENCE POST FIVE-TRACK SYSTEM

PICKET FENCE AND POSTS FOR FOUR-AND FIVE-TRACK SYSTEMS

Fig. 33.

All the gas-pipe railing which had been furnished was stored and used on other contracts where the walls required merely protection for railway operatives, and were not on property lines.

Most of the picket fence was furnished under Contract No. 36, but prices were obtained in a number of other contracts. These prices included the priming with red lead and the erection and painting with two coats of standard Philadelphia and Reading paint. The prices were as follows:

Contract numbers ...	3	4	6	9	10	12	36
Fence per linear foot.	\$1.21	\$1.15	\$0.90	\$1.15	\$1.15	\$1.50	\$1.05

The work under Contract No. 36 included a number of iron gates for the entrances of the various freight yards, an item of \$2 580 for raising the Huntingdon Street foot bridge, and 8 819 ft. of picket fence.

The result of placing the picket fences has been a complete shutting out of the trespassers from the tracks, as the only approach to them is from the freight yards or stations.

Telegraph and Telephone.

Before the elevation of the tracks, the telegraph and telephone system was carried on pole lines throughout the entire extent of the work. In addition to the wires of the Railway Company, those of the Western Union Telegraph Company (operated under a lease) had to be cared for.

As overhead wires during construction would have required constant changing, and would have been much in the way, it was decided to remove all through wires entirely from the line. Accordingly, arrangements were made to carry them in cables through city conduits to Thirty-first and Girard Avenue, and thence in a temporary cable attached to the existing pole line along the main line to West Falls, and thence by the Richmond Branch to Wayne Junction. The wires to yards and stations required for operation were carried through the city streets, by leased attachments on poles of private corporations, to the several yards and stations, and in a few cases along the line during construction in underground temporary trunking. The Railway Company elected to place these wires underground permanently on the solid elevated structure, by cables in vitrified clay ducts surrounded with concrete and in cables attached to the steel viaduct between Brown and Jefferson Streets. As the City was not willing to do more than join in the cost of an overhead pole line, it was

decided to have the Railway Company arrange and pay for the permanent installation, the City to join only in the cost of replacing an overhead pole line. In crossing the bridges, the cables are either carried beneath the steelwork, passing through openings provided in the back walls or above the floor carried through the haunching against the girders through bituminized fiber conduits laid in the concrete. Concrete manholes with steel covers are located at such intervals as the drawing of the cables makes necessary. The laying of the ducts and the drawing of the cables was done by Company forces, after travel was on the tracks and as soon as the fill was sufficiently consolidated.

Permanent Electric Lighting.

The original lighting of the line and the stations was by no means complete. The stations and yards were lighted either by gas or electricity, provided by outside corporations. The lighting of the new work is complete, not only in the yards and at the stations, but also along the entire line, the current being furnished by the power-houses of the Company at Wallace and Huntingdon Streets. The wires are carried from the power-houses along the line in ducts of bituminized fiber, laid in concrete on the masonry and fill sections, and by overhead poles attached to the steel viaduct. As this work was an entire betterment, it was carried out by Company forces in conjunction with the Motive Power Department, and the entire cost borne by the Railway Company.

General Data.

Total number of grade crossings abolished	28
Total number of bridges, not including viaduct	28
Length of four-track viaduct, in feet	3 365
Square feet of bridges, including viaduct	352 400
Total weight of structural steel in bridges and viaduct, in tons	27 180
Number of signal bridges	11
Third-class masonry in retaining walls, in cubic yards	67 500
Concrete masonry in abutments and walls, in cubic yards	151 800
Barrels of cement used	231 800
Embankment, in cubic yards	430 400
Lumber in temporary trestle, in thousands of feet	4 322
Number of contracts	47
Number of emergency orders	52

Station and other buildings	16
Miles of single track, permanent	30.1
Number of reconstructed industrial connections	46
Miles of telegraph and telephone conduit	3.8
Miles of electric light conduit	3.2
Excavation for changes in street grades, in cubic yards	139 620
Total length of sewers, in feet	17 835
Street driveway paving, all kinds, in square yards	73 192
Street sidewalk paving, all kinds, in square yards	31 120
Plans prepared by Railway and approved by City	347
Plans prepared by City and approved by Railway	50
Total number of plans prepared by Railway Company	3 200

PRINCIPAL CONSTRUCTION DATES.

July 6th, 1907. Work begun on Engineer's office, Huntingdon Street.

October 2d, 1907. Work begun on temporary freight yard, Nineteenth and Indiana.

August , 1907. Work begun on sewer contracts.

Between Berks and Broad Streets.

November , 1907. Work begun on temporary tracks, low level.

January 15th, 1908. Work begun on retaining walls, etc., east side.

January 30th, 1909. Two temporary tracks in service, high level, east side.

November 27th, 1909. Two permanent tracks in service, high level, west side.

January 4th, 1911. Schedule trains on all four tracks.

Between Seventeenth and Indiana and Richmond Branch.

October 4th, 1909. Work begun on walls, west side.

October 22d, 1910. Two temporary tracks in service, west side, high level.

June 4th, 1911. Full schedule travel over whole section.

Between Green and Berks Streets.

June 2d, 1909. Work begun on foundations for viaduct.

January 1st, 1911. Two tracks in service on east side, high level, on viaduct and trestle. All grade crossings gone.

December 17th, 1911. Full schedule travel on all tracks.

ACKNOWLEDGMENT.

The ordinance authorizing the work provided that it be carried out by the Chief Engineer of the Philadelphia and Reading Railway Company and the Director of the Department of Public Works of the City of Philadelphia. The original plans were signed on March 28th, 1907, by William Hunter, M. Am. Soc. C. E., as Chief Engineer of the Railway Company, and Mr. John R. Hathaway, as Director of the Department of Public Works; also by Theodore Voorhees, M. Am. Soc. C. E., Vice-President of the Railway Company, and George S. Webster, M. Am. Soc. C. E., Chief Engineer, Bureau of Surveys, City of Philadelphia. Since that time the same officials of the Railway Company have continued in office, while the Directors serving the City have been George R. Stearns, Harry A. Mackey, and Morris L. Cooke. Mr. George F. Baer has been President of the Railway Company, and the Mayors of the City have been, the Hon. John Weaver, the Hon. John E. Reyburn, and the Hon. Rudolph Blankenburg.

The engineering work, in the preparation of the plans and specifications, as well as the work of construction, was carried out by the Railway Company under the direction of William Hunter, M. Am. Soc. C. E., as Chief Engineer, with the writer and Messrs. E. Chamberlain and Charles H. Hitchcock as Assistant Engineers; and by the City under the direction of George S. Webster, M. Am. Soc. C. E., as Chief Engineer, Bureau of Surveys, by Mr. James W. Phillips as Assistant Engineer in charge, and Assistant Engineers D. Jones Lucas, M. Am. Soc. C. E., Silas G. Griffith, H. T. Shelley, Arthur G. Singer, and Charles H. Stevens.

During the entire time, all bridge plans were passed upon by W. B. Riegner, M. Am. Soc. C. E., Engineer of Bridges, Philadelphia and Reading Railway, and George E. Datesman, M. Am. Soc. C. E., was Principal Assistant Engineer, Bureau of Surveys.

The Operating Department of the Railway Company rendered most valuable assistance throughout the entire work. Mr. Agnew T. Dice, General Manager, and the following officers of the Philadelphia Division, J. B. Warrington, Superintendent; H. C. Smith, M. Am. Soc. C. E., Division Engineer; Geo. W. Snook, Supervisor; and J. E. Peters and H. Mansfield, Trainmasters.

To Mr. A. H. Yocum, Signal Engineer, and to Mr. David S. Gendell,

Engineer of Erection, McClintic-Marshall Construction Company, the writer desires to express his appreciation for assistance in the preparation of details of this paper.

To all these gentlemen, the writer begs to acknowledge kind assistance, advice, and courtesy rendered at all times, and to his superior officers for permission to present the data contained in this paper.

AMERICAN SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

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TESTS OF CREOSOTED TIMBER.*

By W. B. Gregory, M. Am. Soc. C. E.

In a previous paper,† under the same title, the writer reported the tests of fourteen beams, which were taken from a trestle of a railroad near New Orleans, and, at the time of the tests, had been in use for 26 years. The specifications for treating this timber with creosote were given in the former paper, and need not be repeated here.

Recently, other beams, having been in use more than 29 years, were removed from the trestle and tested to destruction. The material was similar to that tested previously, and consisted of southern pine stringers having a cross-section approximately 6 by 16 in. and a length of 30 ft. For the purpose of testing, each beam was cut into two parts, each about 15 ft. long. It is the purpose of this paper to report the recent tests.

Method of Testing.

The tests were made exactly as in the former case, using a Riehlé 100 000-lb. machine, in the Experimental Engineering Laboratory of Tulane University of Louisiana. In order to make this discussion complete, the methods as stated in the former paper are repeated here:

"The machine is provided with a cast-iron beam for cross-bending tests. The distance between supports was 12 ft. The method of support was as follows: Each end of the beam was provided with a steel roller which rested on the cast-iron beam of the testing machine, while above the roller, and, directly under the beam tested, there was a steel plate 6 by 8 in. in area and 1 in. thick. The area was suf-

* This paper will not be presented at any meeting, but written communications on the subject are invited for publication with it in *Transactions*.

† *Transactions*, Am. Soc. C. E., Vol. LXX, p. 37.

ficiently great to distribute the load and prevent the shearing of the fibers of the wood. The head of the Riehlé machine is 10 in. wide. A plate, $\frac{3}{8}$ in. thick, 6 in. wide and 18 in. long, was placed between the head of the machine and the beam tested.

"The deflection was measured on both sides of each beam by using silk threads stretched on each side from nails driven about 2 in. above the bottom of the beam and directly over the rollers which formed the supports. From a small piece of wood, tacked to the bottom of the beam at its center and projecting at the sides, the distance to these threads was measured. These measurements were taken to the nearest hundredth of an inch. The mean of the deflections was taken as the true deflection for any load.

"In computing the various quantities shown in Table 1, the summary of results, the load has been assumed as concentrated at the center of the beam. While it is true that the load was spread over a length of about 12 in., due to the width of the head of the machine and the plate between it and the beam tested, it is also true that there were irregularities, such as bolt-holes and, in some cases, abrasions due to wear, that could not well be taken into account. Hence, it was deemed sufficiently accurate to consider the load as concentrated. Besides the horizontal bolt-holes, shown in the photographs, there were vertical bolt-holes, at intervals in all the beams. The latter were $\frac{3}{4}$ in. in diameter, and in every case they were sufficiently removed from the center of the length of the beam to allow the maximum moment at the reduced section to be relatively less than that at the center of the beam. For this reason, no correction was made for these holes. The broken beams often showed that rupture started at, or was influenced by, some of the holes, especially the horizontal ones."

In the previous paper the writer made some comparisons of results with those of large timbers tested elsewhere. The conclusion was:

"The number of tests was not sufficient to settle questions of average strength or other qualities. It will be seen, however, that the treated timber 26 years old compares favorably with the new untreated timber."

Although the tests now reported give average results slightly lower than those in the former paper, the maximum breaking load occurred in the recent tests, and the minimum of all breaking loads was found in the first set of tests. In view of these facts, it appears that the conclusions apply to the later tests of this material, which, as stated previously, has been in use more than 29 years.

The writer is indebted to his colleague, Professor J. M. Robert, of Tulane University, for valuable assistance in this work.

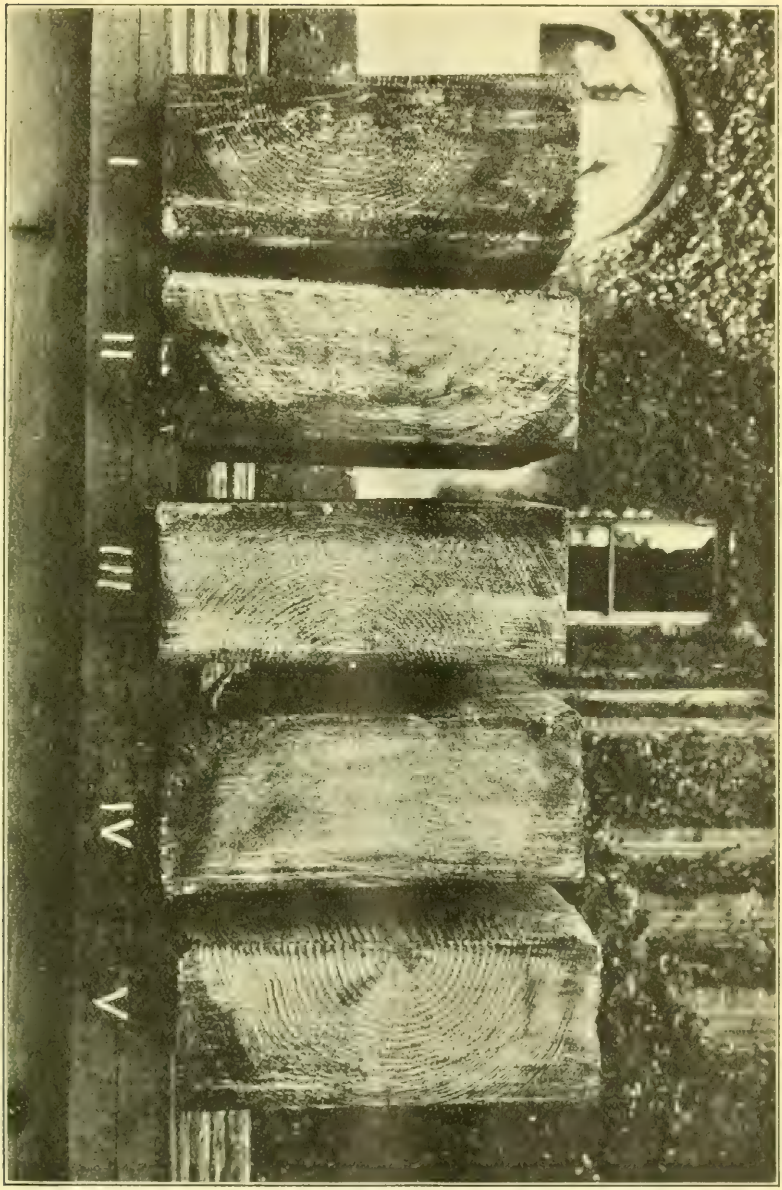

FIG. 1.—SECTIONS OF BEAMS NEAR THE CENTER.

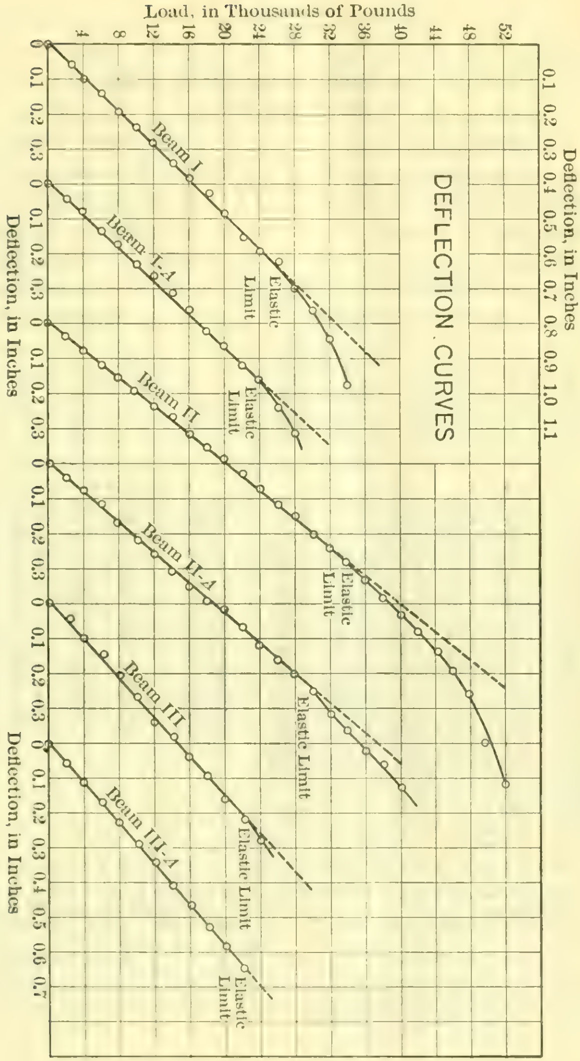
DEFLECTION CURVES
Load, in Thousands of Pounds
Deflection, in Inches
Beam I
Beam I-A
Beam II
Beam II-A
Beam III
Beam III-A
Elastic Limit

FIG. 2.

TABLE 1.—LOAD AND DEFLECTION LOG; BEAM I. LOBLOLLY, 5 RINGS PER INCH.

Beam I.
Date: November 8th, 1912.
$l = 12$ ft.; b (mean) $= 6.03$ in.;
h (mean) $= 15.89$ in.;
$c = 7.945$ in. Time = ...

Beam I-*A*.
Date: November 6th, 1912.
$l = 12$ ft.; b (mean) $= 6.22$ in.;
h (mean) $= 16.00$ in.;
$c = 8.00$ in. Time = 32 min.

No.	*P*	Deflection, in Inches.					*P*	Deflection, in Inches.				
	Load, in pounds.	Reading.	Total deflection.	Reading.	Total deflection.	Mean total deflection.	Load, in pounds.	Reading.	Total deflection.	Reading.	Total deflection.	Mean total deflection.
1	0	1.08	0	1.12	0	0	0	1.15	0	1.20	0	0
2	2 000	1.14	0.06	1.18	0.06	0.06	2 000	1.20	0.05	1.24	0.04	0.045
3	4 000	1.18	0.10	1.22	0.10	0.10	4 000	1.24	0.09	1.28	0.08	0.085
4	6 000	1.22	0.14	1.26	0.14	0.14	6 000	1.29	0.14	1.33	0.13	0.135
5	8 000	1.28	0.20	1.31	0.19	0.195	8 000	1.34	0.19	1.37	0.17	0.18
6	10 000	1.32	0.24	1.36	0.24	0.24	10 000	1.39	0.24	1.42	0.22	0.23
7	12 000	1.38	0.30	1.40	0.28	0.29	12 000	1.43	0.28	1.46	0.26	0.27
8	14 000	1.42	0.34	1.46	0.34	0.34	14 000	1.47	0.32	1.51	0.31	0.315
9	16 000	1.47	0.39	1.50	0.38	0.385	16 000	1.52	0.37	1.56	0.36	0.365
10	18 000	1.52	0.44	1.54	0.42	0.43	18 000	1.58	0.43	1.61	0.41	0.42
11	20 000	1.57	0.49	1.60	0.48	0.485	20 000	1.63	0.48	1.66	0.46	0.47
12	22 000	1.64	0.56	1.66	0.44	0.55	22 000	1.68	0.53	1.71	0.51	0.52
13	24 000	1.67	0.59	1.71	0.59	0.59	24 000	1.73	0.58	1.75	0.55	0.565
14	26 000	1.71	0.63	1.74	0.62	0.625	26 000	1.80	0.65	1.83	0.63	0.64
15	28 000	1.78	0.70	1.82	0.70	0.70	28 000	1.86	0.71	1.90	0.70	0.705
16	30 000	1.84	0.76	1.88	0.76	0.76	29 800	Broke.				
17	32 000	1.93	0.85	1.96	0.84	0.845						
18	34 000	1.95	0.87	2.20	1.08	0.975						
19	34 350	Break.										
20	36 000	2.19		2.46								
21	38 000	2.34		2.62								
22	38 450	Maximum load.										

Beam I: 32 000 lb., First Crack; 38 450 lb., Failed.

At Elastic Limit: Load, 26 000 lb.; deflection, 0.625 in.: *S*, 3 680 lb.
Maximum: Load, 38 450 lb.; deflection, ...; *S*, 5 450 lb.
$E = 1\ 283\ 000$ lb.

Beam I-*A*: .....lb., First Crack; 29 800 lb., Failed.

At Elastic Limit: Load, 24 000 lb.; deflection, 0.565 in.; *S*, 3 252 lb.
Maximum: Load, 29 800 lb.; deflection, ...; *S*, 4 038 lb.
$E = 1\ 243\ 000$ lb.

TABLE 2.—LOAD AND DEFLECTION LOG; BEAM II. LONG LEAF, 11 RINGS PER INCH.

Beam II.	Beam II-*A*.
Date: November 15th, 1912.	Date: November 13th, 1912.
$l = 12$ ft.; b (mean) $= 6.08$ in.; h (mean) $= 15.75$ in.; $c = 7.875$ in. Time $=$ 10.10–11.20 A.M.	$l = 12$ ft.; b (mean) $= 5.97$ in.; h (mean) $= 15.97$ in.; $c = 7.985$ in. Time $= 40$ min.

No.	P	DEFLECTION, IN INCHES.					P	DEFLECTION, IN INCHES.				
	Load, in pounds.	Reading.	Total deflection.	Reading.	Total deflection.	Mean total deflection.	Load, in pounds.	Reading.	Total deflection.	Reading.	Total deflection.	Mean total deflection.
1	0	1.17	0	1.07	0	0	0	0.80	0	1.00	0	0
2	2 000	1.21	0.04	1.10	0.03	0.035	2 000	0.84	0.04	1.04	0.04	0.04
3	4 000	1.26	0.09	1.14	0.07	0.08	4 000	0.88	0.08	1.08	0.08	0.08
4	6 000	1.30	0.13	1.18	0.11	0.12	6 000	0.92	0.12	1.12	0.12	0.12
5	8 000	1.34	0.17	1.21	0.14	0.155	8 000	0.96	0.16	1.18	0.18	0.17
6	10 000	1.39	0.22	1.24	0.17	0.195	10 000	1.00	0.20	1.24	0.24	0.22
7	12 000	1.42	0.25	1.29	0.22	0.235	12 000	1.04	0.24	1.28	0.28	0.26
8	14 000	1.46	0.29	1.33	0.26	0.275	14 000	1.07	0.27	1.34	0.34	0.305
9	16 000	1.50	0.33	1.37	0.30	0.315	16 000	1.12	0.32	1.38	0.38	0.35
10	18 000	1.54	0.37	1.41	0.34	0.355	18 000	1.16	0.36	1.42	0.42	0.39
11	20 000	1.58	0.41	1.44	0.37	0.390	20 000	1.18	0.38	1.46	0.46	0.42
12	22 000	1.62	0.45	1.48	0.41	0.430	22 000	1.22	0.42	1.52	0.52	0.47
13	24 000	1.66	0.49	1.53	0.46	0.475	24 000	1.26	0.46	1.58	0.58	0.52
14	26 000	1.70	0.53	1.58	0.51	0.520	26 000	1.30	0.50	1.62	0.62	0.56
15	28 000	1.74	0.57	1.61	0.54	0.555	28 000	1.34	0.54	1.66	0.66	0.60
16	30 000	1.78	0.61	1.66	0.59	0.600	30 000	1.38	0.58	1.72	0.72	0.65
17	32 000	1.82	0.65	1.70	0.63	0.640	32 000	1.41	0.61	1.82	0.82	0.715
18	34 000	1.87	0.70	1.73	0.66	0.680	34 000	1.46	0.66	1.86	0.86	0.76
19	36 000	1.91	0.74	1.80	0.73	0.735	36 000	1.50	0.70	1.94	0.94	0.82
20	38 000	1.96	0.79	1.85	0.78	0.785	38 000	1.54	0.74	1.98	0.98	0.86
21	40 000	2.00	0.83	1.90	0.83	0.830	40 000	1.58	0.78	2.06	1.06	0.92
22	42 000	2.06	0.89	1.95	0.88	0.885	42 000					
23	44 000	2.11	0.94	2.00	0.93	0.935						
24	46 000	2.17	1.00	2.06	0.99	0.995						
25	48 000	2.24	1.07	2.12	1.05	1.060						
26	50 000	2.34	1.17	2.30	1.23	1.200						
27	52 000	2.44	1.27	2.43	1.36	1.315						
28	54 000											
29	56 000											

Beam II:

47 900 lb., First Crack ; 55 060 lb., Failed.

At Elastic Limit : Load, 34 000 lb.; deflection, 0.680 in.; S, 4 870 lb.

Maximum : Load, 55 060 lb.; deflection, ... ; S, 7 890 lb.

$E = 1\,573\,000$ lb.

Sheared along neutral axis.

Beam II-A:

31 500 lb., First Crack ; 42 000 lb., Failed.

At Elastic Limit : Load, 30 000 lb.; deflection, 0.650 in.; S, 4 260 lb.

Maximum : Load, 42 000 lb.; deflection, ... ; S, 5 960 lb.

$E = 1\,418\,000$ lb.

TABLE 3.—LOAD AND DEFLECTION LOG; BEAM III. LOBLOLLY.

Beam III.
Date: November 20th, 1912.
$l = 12$ ft.; b (mean) $= 5.86$ in.;
h (mean) $= 15.50$ in.;
$c = 7.75$ in. Time $= 30$ min.

No.	P Load, in pounds.	Deflection, in Inches. Reading.	Total deflection.	Reading.	Total deflection.	Mean total deflection.
1	0	1.24	0	1.19	0	0
2	2 000	1.29	0.05	1.24	0.05	0.05
3	4 000	1.33	0.09	1.30	0.11	0.10
4	6 000	1.38	0.14	1.34	0.15	0.145
5	8 000	1.43	0.19	1.41	0.22	0.205
6	10 000	1.49	0.25	1.48	0.29	0.270
7	12 000	1.58	0.34	1.53	0.34	0.340
8	14 000	1.59	0.35	1.60	0.41	0.380
9	16 000	1.65	0.41	1.65	0.46	0.435
10	18 000	1.71	0.47	1.70	0.51	0.490
11	20 000	1.77	0.53	1.78	0.59	0.560
12	22 000	1.83	0.59	1.83	0.64	0.615
13	24 000	1.89	0.65	1.90	0.71	0.680

21 500 lb., First Crack; 25 700 lb., Failed.

At Elastic Limit: Load, 22 000 lb.; deflection, 0.615 in.; S, 3 380 lb.
Maximum: Load, 25 700 lb.; deflection........; S, 3 945 lb.

$E = 1\,224\,000$ lb.

Broke at a point 18 in. from center; bottom fibers failed in tension at bolt-hole ⅞ in. in diameter; axis of hole vertical.

Beam III-A.
Date: November 16th, 1912.
$l = 12$ ft.; b (mean) $= 6.03$ in.;
h (mean) $= 15.55$ in.;
$c = 7.775$ in. Time $=$ ......

No.	P Load, in pounds.	Deflection, in Inches. Reading.	Total deflection.	Reading.	Total deflection.	Mean total deflection.
1	0	0.96	0	0.97	0	0
2	200	1.01	0.05	1.03	0.06	0.055
3	4 000	1.07	0.11	1.08	0.11	0.11
4	6 000	1.12	0.16	1.14	0.17	0.165
5	8 000	1.18	0.22	1.20	0.23	0.225
6	10 000	1.24	0.28	1.26	0.29	0.285
7	12 000	1.29	0.33	1.32	0.35	0.34
8	14 000	1.36	0.40	1.38	0.41	0.405
9	16 000	1.42	0.46	1.44	0.47	0.465
10	18 000	1.48	0.52	1.50	0.53	0.525
11	20 000	1.54	0.58	1.56	0.59	0.585
12	22 000	1.60	0.64	1.62	0.65	0.645
13	22 600	Broke.				

22 000 lb., First Crack; 22 600 lb., Failed.

At Elastic Limit: Load, 22 000 lb.; deflection, 0.645 in.; S, 3 260 lb.
Maximum: Load, 22 600 lb.; deflection, ...; S, 3 350 lb.

$E = 1\,124\,000$ lb.

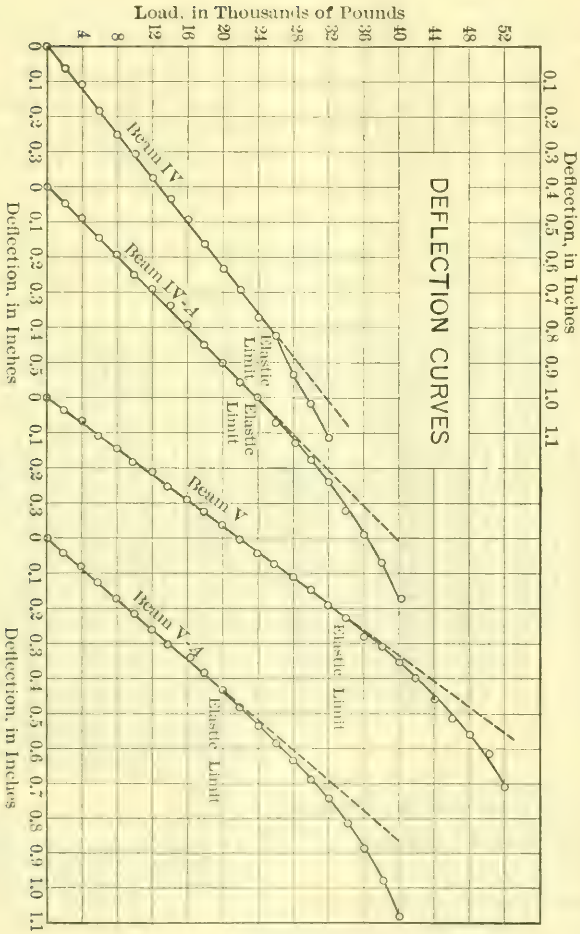
DEFLECTION CURVES
Load, in Thousands of Pounds
Deflection, in Inches
Beam IV
Beam IV-A
Beam V
Beam V-A
Elastic Limit

FIG. 3.

TABLE 4.—Load and Deflection Log; Beam IV. Long Leaf.

Beam IV.
Date: November 27th, 1912.
$l = 12$ ft.; b (mean) $= 6.46$ in.;
h (mean) $= 15.71$ in.;
$c = 7.855$ in. Time $= 1$ hour 15 min.

No.	P: Load, in pounds.	Deflection, in Inches: Reading.	Total deflection.	Reading.	Total deflection.	Mean total deflection
1	0	1.16	0	1.24	0	0
2	2 000	1.23	0.07	1.30	0.06	0.065
3	4 000	1.28	0.12	1.34	0.10	0.110
4	6 000	1.36	0.20	1.41	0.17	0.185
5	8 000	1.41	0.25	1.49	0.25	0.250
6	10 000	1.47	0.31	1.54	0.30	0.305
7	12 000	1.52	0.36	1.62	0.38	0.370
8	14 000	1.59	0.43	1.68	0.44	0.435
9	16 000	1.65	0.49	1.74	0.50	0.495
10	18 000	1.73	0.57	1.80	0.56	0.565
11	20 000	1.78	0.62	1.88	0.64	0.630
12	22 000	1.85	0.69	1.94	0.70	0.695
13	24 000	1.92	0.76	2.02	0.78	0.770
14	26 000	1.97	0.81	2.08	0.84	0.825
15	28 000	2.09	0.93	2.18	0.94	0.935
16	30 000	2.17	1.01	2.26	1.02	1.015
17	32 000	2.26	1.10	2.36	1.12	1.110
18	34 000					

31 500 lb., First Crack; 33 740 lb., Failed.

At Elastic Limit: Load, 26 000 lb.; deflection, 0.825 in.; S, 3 530 lb.

Maximum Load: 33 740 lb.; deflection, ...; S, 4 575 lb.

$E = 939\,000$ lb.

Bottom fibers broke in tension near center of specimen.

Beam IV-A.
Date: November 22d, 1912.
$l = 12$ ft.; b (mean) $= 6.50$ in.;
h (mean) $= 16.12$ in.;
$c = 8.06$ in. Time $= 35$ min.

No.	P: Load, in pounds.	Deflection, in Inches: Reading.	Total deflection.	Reading.	Total deflection.	Mean total deflection.
1	0	1.08	0	1.21	0	0
2	2 000	1.13	0.05	1.26	0.05	0.05
3	4 000	1.17	0.09	1.31	0.10	0.095
4	6 000	1.22	0.14	1.36	0.15	0.145
5	8 000	1.27	0.19	1.41	0.20	0.195
6	10 000	1.33	0.25	1.46	0.25	0.25
7	12 000	1.37	0.29	1.51	0.30	0.295
8	14 000	1.42	0.34	1.56	0.35	0.345
9	16 000	1.47	0.39	1.61	0.40	0.395
10	18 000	1.52	0.44	1.67	0.46	0.45
11	20 000	1.57	0.49	1.72	0.51	0.50
12	22 000	1.62	0.54	1.78	0.57	0.555
13	24 000	1.67	0.59	1.82	0.61	0.60
14	26 000	1.72	0.64	1.91	0.70	0.67
15	28 000	1.78	0.70	1.95	0.74	0.72
16	30 000	1.84	0.76	2.01	0.80	0.78
17	32 000	1.89	0.81	2.08	0.87	0.84
18	34 000	1.97	0.89	2.16	0.95	0.92
	36 000	2.02	0.94	2.24	1.03	0.985
	38 000	2.11	1.03	2.32	1.11	1.07
	40 000	2.20	1.12	2.43	1.22	1.17
	42 000					

38 250 lb., First Crack; 40 130 lb., Failed.

At Elastic Limit: Load, 24 000 lb.; deflection, 0.600 in.; S, 3 065 lb.

Maximum: Load, 40 130 lb.; deflection, ...; S, 5 120 lb.

$E = 1\,095\,000$ lb.

TABLE 5.—LOAD AND DEFLECTION LOG; BEAM V. LOBLOLLY.

Beam V.	Beam V-*A*.
Date: November 29th, 1912.	Date: December 6th, 1912.
l = 12 ft.; b (mean) = 6.09 in.;	l = 12 ft.; b (mean) = 6.25 in.;
h (mean) = 15.93 in.;	h (mean) = 15.94 in.;
c = 7.965 in. Time = ...	c = 7.97 in. Time = 33 min.

No.	*P*	Deflection, in Inches.					*P*	Deflection, in Inches.				
	Load, in pounds.	Reading.	Total deflection.	Reading.	Total deflection.	Mean total deflection.	Load, in pounds.	Reading.	Total deflection.	Reading.	Total deflection.	Mean total deflection.
1	0	1.085	0	0.95	0	0	0	0.98	0	0.92	0	0
2	2 000	1.11	0.03	0.99	0.4	0.035	2 000	1.02	0.04	0.96	0.04	0.04
3	4 000	1.14	0.06	1.02	0.7	0.065	4 000	1.06	0.08	1.00	0.08	0.08
4	6 000	1.18	0.10	1.06	0.11	0.105	6 000	1.10	0.12	1.05	0.13	0.125
5	8 000	1.22	0.14	1.10	0.15	0.145	8 000	1.14	0.16	1.10	0.18	0.17
6	10 000	1.26	0.18	1.14	0.19	0.185	10 000	1.18	0.20	1.14	0.22	0.21
7	12 000	1.29	0.21	1.16	0.21	0.210	12 000	1.23	0.25	1.18	0.26	0.255
8	14 000	1.33	0.25	1.20	0.25	0.250	14 000	1.28	0.30	1.22	0.30	0.30
9	16 000	1.37	0.29	1.24	0.29	0.290	16 000	1.32	0.34	1.26	0.34	0.34
10	18 000	1.41	0.33	1.27	0.32	0.325	18 000	1.36	0.38	1.30	0.38	0.38
11	20 000	1.44	0.36	1.31	0.36	0.360	20 000	1.41	0.43	1.35	0.43	0.43
12	22 000	1.48	0.40	1.35	0.40	0.400	22 000	1.46	0.48	1.40	0.48	0.48
13	24 000	1.52	0.44	1.39	0.44	0.440	24 000	1.51	0.53	1.45	0.53	0.53
14	26 000	1.55	0.47	1.42	0.47	0.470	26 000	1.56	0.58	1.50	0.58	0.58
15	28 000	1.60	0.52	1.45	0.50	0.510	28 000	1.61	0.63	1.55	0.63	0.63
16	30 000	1.63	0.55	1.49	0.54	0.545	30 000	1.67	0.69	1.60	0.68	0.685
17	32 000	1.68	0.60	1.53	0.58	0.590	32 000	1.73	0.75	1.65	0.73	0.74
18	34 000	1.72	0.64	1.56	0.61	0.625	34 000	1.80	0.82	1.72	0.80	0.81
19	36 000	1.77	0.69	1.61	0.66	0.675	36 000	1.88	0.90	1.80	0.88	0.89
20	38 000	1.79	0.71	1.65	0.70	0.705	38 000	1.98	1.00	1.87	0.95	0.975
21	40 000	1.84	0.76	1.69	0.74	0.750	40 000	2.09	1.11	1.97	1.05	1.08
22	42 000	1.88	0.80	1.75	0.80	0.800	41 275	Broke.				
23	44 000	1.94	0.86	1.80	0.85	0.855						
24	46 000	2.00	0.92	1.85	0.90	0.91						
25	48 000	2.05	0.97	1.90	0.95	0.960						
26	50 000	2.10	1.02	1.95	1.00	1.01						
27	52 000	2.20	1.12	2.05	1.10	1.11						
28	54 000	Broke.										

Beam V.	Beam V-*A*.
16 000 lb., First Crack; 54 000 lb., Failed.	32 000 lb., First Crack; 41 275 lb., Failed.
At Elastic Limit: Load, 38 000 lb.; deflection, 0.705 in.; *S*, 5 310 lb.	At Elastic Limit: Load, 22 000 lb.; deflection, 0.480 in.; *S*, 2 990 lb.
Maximum: Load, 54 000 lb.; deflection, ...; *S*, 7 550 lb.	Maximum: Load, 41 275 lb.; deflection, ...; *S*, 5 620 lb.
E = 1 633 000 lb.	E = 1 350 000 lb.

TABLE 6.—SUMMARY OF TESTS.

Number of beam.	Top of butt of log.	b Width, in inches.	h Height, in inches.	I $I = \frac{b h^3}{12}$	LOADS. Actual, at elastic limit.	LOADS. Maximum.	$S = \frac{P l c}{4 I}$ At elastic limit.	$S = \frac{P l c}{4 I}$ Maximum.	d, in inches. At elastic limit.	E $E = \frac{P l^3}{48 d I}$	Weight, in pounds per cubic foot.	Kind
I	T	6.03	15.89	2 015	26 000	38 450	3 680	5 450	0.625	1 283 000	43.3	Coarse-grained loblolly.
I-A..	B	6.22	16.00	2 125	24 000	29 800	3 252	4 038	0.565	1 243 000	42.6	
II....	T	6.08	15.75	1 978	34 000	55 060	4 870	7 890	0.680	1 573 000	43.7	Long-leaf pine.
II-A.	B	5.97	15.97	2 025	30 000	42 000	4 260	5 960	0.650	1 418 000	47.6	
III ..	T	5.86	15.50	1 818	22 000	25 700	3 380	3 945	0.615	1 224 000	39.4	Coarse-grained loblolly.
III-A	B	6.03	15.55	1 889	22 000	22 600	3 260	3 350	0.645	1 124 000	39.6	
IV...	T	6.46	15.61	2 086	26 000	33 740	3 530	4 575	0.825	939 000	41.9	Long-leaf pine.
IV-A	B	6.50	16.12	2 271	24 000	40 130	3 065	5 120	0.600	1 095 000	45.5	
V	B	6.09	15.93	2 051	38 000	54 000	5 310	7 550	0.705	1 633 000	45.1	Coarse-grained loblolly.
V-A..	T	6.25	15.94	2 109	22 000	41 275	2 990	5 620	0.480	1 350 000	42.5	

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PAPERS AND DISCUSSIONS

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THE STORAGE OF FLOOD-WATERS FOR IRRIGATION: A STUDY OF THE SUPPLY AVAILABLE FROM SOUTHERN CALIFORNIA STREAMS.

By A. M. Strong, Assoc. M. Am. Soc. C. E.

To be Presented September 3d, 1913.

Many of the richest sections of California are valleys and plains at the foot of abrupt mountain ranges. The climate is suitable for raising citrus and semi-tropical fruits, but, due to the long summer droughts, this can only be done where there is sufficient water for irrigation. The value of the products has been great, and, beginning with the small irrigation ditches of the Spanish days, the most perfect systems of irrigation in the United States have been built up.

The source of all the water used in these sections is in the streams coming from the neighboring mountain ranges. It is secured by direct diversion, by storage in surface reservoirs, or by pumping from the underground gravel beds fed by these streams. A large part of the total run-off of the streams comes during a short rainy season, or, in the case of those heading in the highest ranges, with the first hot weather of the summer. Rainfall records for 34 years in Los Angeles show that an average of 75% fell during December, January, February, and March, and the run-off of Southern California streams shows a corresponding percentage. In the case of some of the streams head-

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

ing in the snow fields of the Sierra Nevadas, from 12 to 15% of the total run-off comes during a 10-day period in June or July. In the middle and late summer months, when irrigation is needed most, the streams have reached their low-water flow. For this reason many large storage reservoirs have been built, and large areas are irrigated by pumping from underground basins.

As a rule, the area of land which can be placed under cultivation is measured by the quantity of water available, and great expense is warranted in increasing the supply. In many places there are no practical reservoir sites directly on the streams, and in others the available reservoir capacity is only a small part of the total run-off. Even where conditions are most favorable for storage, there are many seasons when it is insufficient for the total flood run-off. Irrigation has now reached a point where all the flow available for direct diversion is in use, and, particularly in Southern California, reservoirs have been constructed on all available sites on the streams. In many places the pumping draft from underground basins is as great as the inflow, or greater. The percentage of the total run-off which can be put to beneficial use can be increased only by diverting the flood flow to reservoirs outside of the natural drainage, or by increasing the flow into the underground basins.

The question of the quantity of water available for storage in this way is becoming very important wherever the water supply for irrigation is extensively developed. The principal problem is the diversion of a large flow from the flood-water for a short time and its storage for a smaller flow during the entire irrigation season. This is now being done in a number of the late projects in various parts of the West. The object of the investigation described in this paper was to get some idea as to the quantity of water now being wasted, but still available for storage in this way. The San Gabriel River, with unusually good records of run-off, was taken as a typical case.

This river drains a large portion of the southern slope of the San Gabriel Range, and is one of the three principal streams of Southern California. The mountain area above the gauging station contains 222 sq. miles, and is somewhat rectangular, as shown on the map, Fig. 1. The elevations range from 1 000 ft. at the gauging station to 10 080 ft. at San Antonio Peak, with an average of about 4 000 ft. To an elevation of about 5 000 ft., the ground is covered with a dense

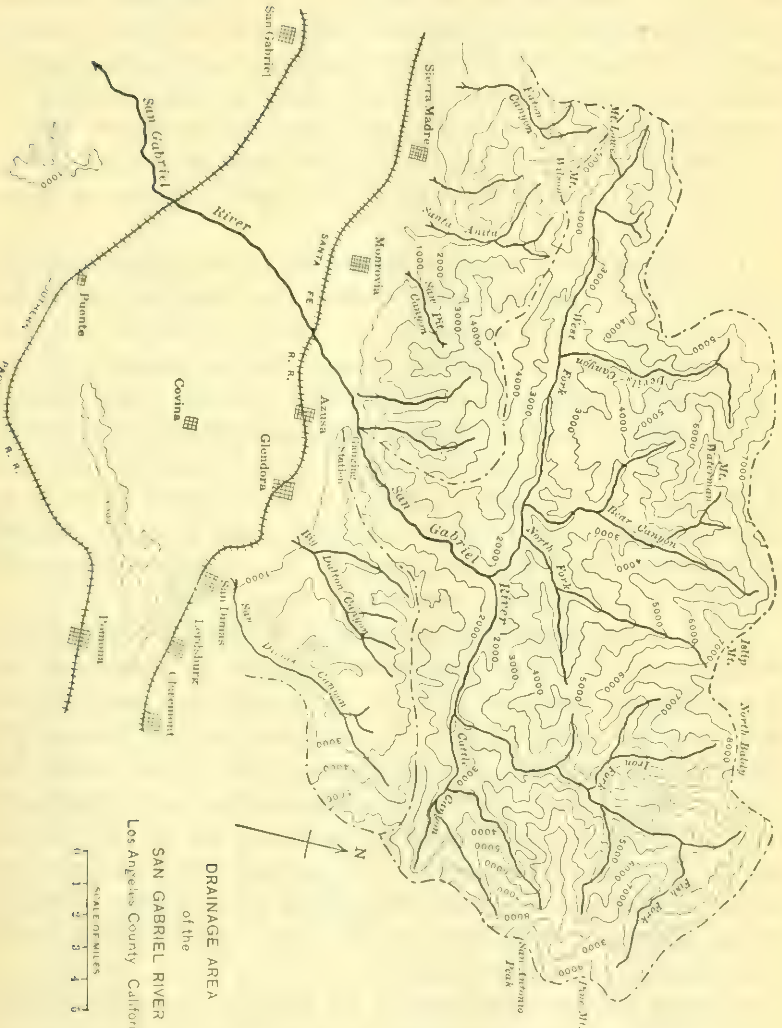

DRAINAGE AREA
of the
SAN GABRIEL RIVER
Los Angeles County California
SCALE OF MILES
San Gabriel River
Sierra Madre
Monrovia
Puente
Covina
Azusa
Glendora
San Dimas
Lordsburg
Claremont
Pomona
SANTA FE R. R.
PACIFIC R. R.
Mt. Lowe
Mt. Wilson
Eaton Canyon
Santa Anita
San Gabriel
West Fork
Devils Canyon
Mt. Waterman
Bear Canyon
North Fork
Mt. Islip
North Baldy
Iron Fork
Fish Fork
Cattle Canyon
San Antonio Peak
Big Dalton Canyon
Gauging Station
N

FIG. 1

growth of brush; above that level there is more or less timber. The geological formation is granite, with a thin soil covering. Precipitation is in the form of rain, except on the higher peaks. Though there are no rainfall records from any station inside the mountain drainage area, practically all the precipitation comes from the general storms shown on the records for the neighboring valley stations, the quantity increasing with the elevation. Below the gauging station, which is at the foot of the mountains, the river flows across the San Gabriel Valley, in a wide gravel wash, through a break in the foot-hills at the Narrows, and across the Coastal Plain to the Pacific Ocean, a distance of about 35 miles.

The gauging station was established by the United States Geological Survey in 1896, and the records obtained since 1898 are said to be very satisfactory. The records of the flow from 1896 to 1902 are published in the form of monthly averages, and are shown in Fig. 2. Since 1902 the daily flow is published in the annual Water Supply Papers giving the surface supply of the United States. The station is well above all tributaries of the river and below the diversion of the power and irrigation canals. A careful record of the flow in the canals is kept, and is given in separate tables, but it is combined with the flow at the gauging station in the diagrams showing the daily flow of the river from 1902 to 1910. (Figs. 3 to 10.)

Years of experience have shown that, for irrigation and power purposes, 80 sec-ft. is the greatest flow that can be counted on for any considerable length of time, and, as a result, this has been the capacity of the diversion canals. Except during the rainy season, this diversion capacity is as great as the total flow of the stream, or greater. Fig. 11 shows the number of days, during each of the eight years, in which the flow exceeded 80 sec-ft., and the duration of the varying flows up to 1 000 sec-ft. The average for those years for which the flow was more than 80 sec-ft. is 148, and that in which it was more than 1 000 sec-ft. is 13½ days. The individual years differ greatly from this average.

No place has ever been found on the drainage area where storage could be obtained, and all the flow in excess of 80 sec-ft. runs down the gravel wash in the San Gabriel Valley. Here a certain quantity passes into the underground storage in the gravel beds, and supplies the numerous pumping plants scattered over the surface of the under-

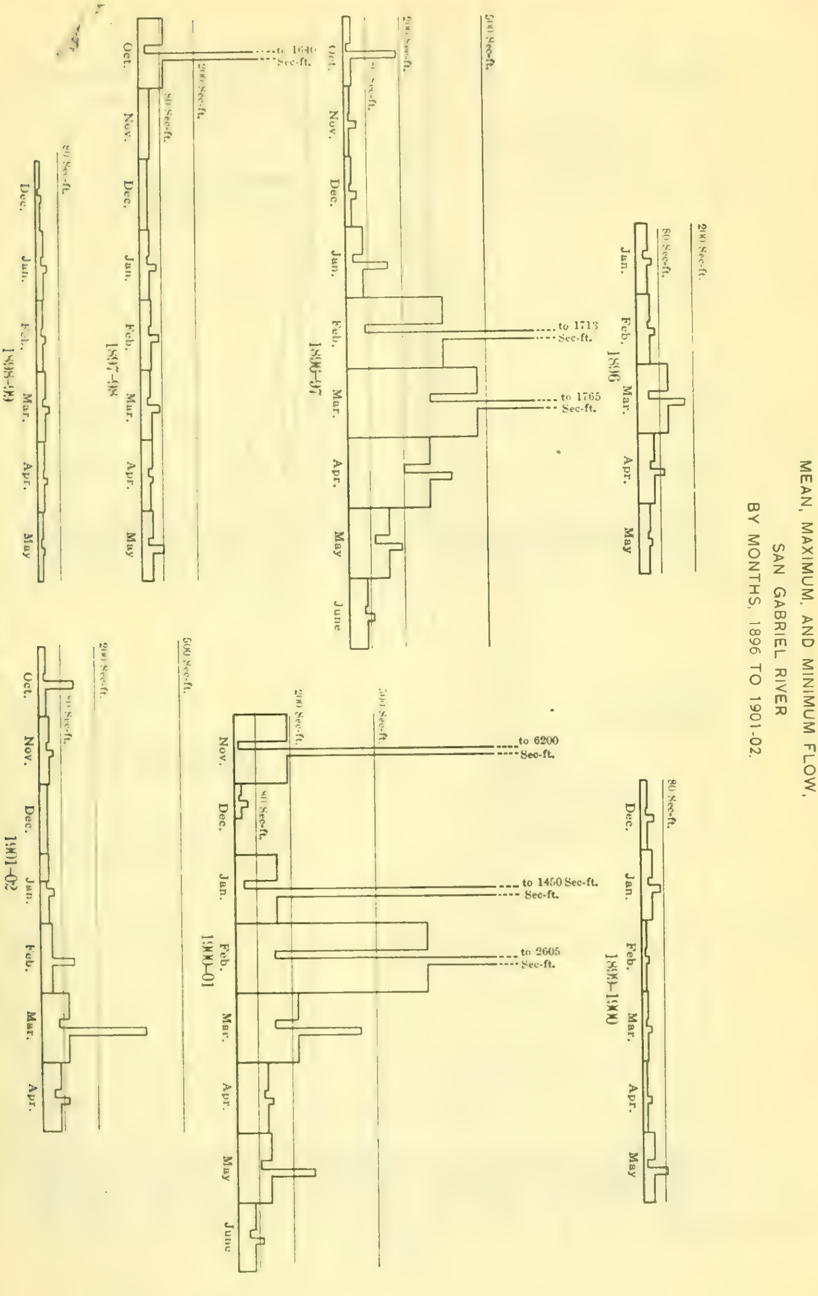
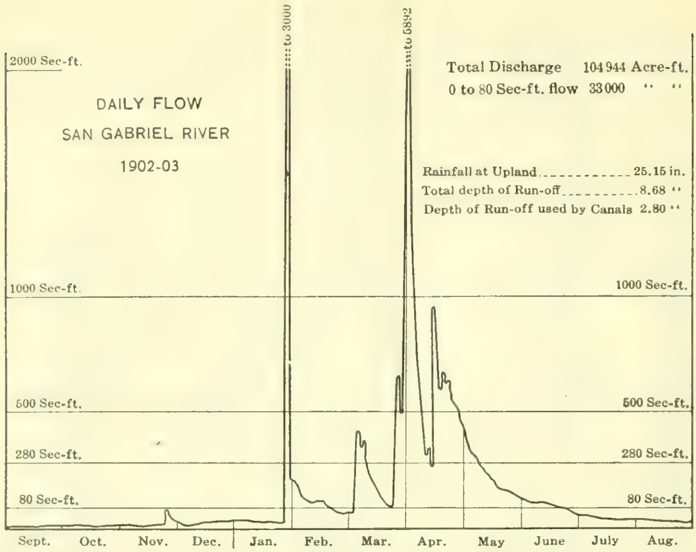
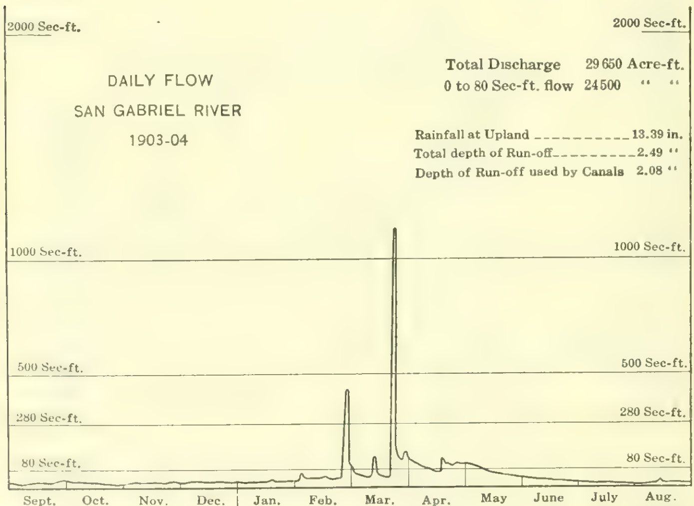

MEAN, MAXIMUM, AND MINIMUM FLOW,
SAN GABRIEL RIVER
BY MONTHS, 1896 TO 1901-02.
1896
1896-97
1897-98
1898-99
1899-1900
1900-01
1901-02
to 1713 Sec-ft.
to 1765 Sec-ft.
to 1640 Sec-ft.
to 6200 Sec-ft.
to 1450 Sec-ft.
to 2605 Sec-ft.
500 Sec-ft.
200 Sec-ft.
80 Sec-ft.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May
June

FIG. 2.



	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.
Depth of Run-off	0.02 in.	0.03 in.	0.10 in.	0.16 in.	0.77 in.	0.48 in.	1.34 in.	3.98 in.	1.13 in.	0.48 in.	0.22 in.	0.15 in.
Rainfall at Upland	0 "	0.41 "	2.05 "	2.54 "	3.97 "	2.10 "	9.45 "	4.00 "	0.63 "	0 "	0 "	0 "

FIG. 3.



	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.
Depth of Run-off	0.12 in.	0.13 in.	0.12 in.	0.13 in.	0.13 in.	0.23 in.	0.58 in.	0.46 in.	0.34 in.	0.12 in.	0.07 in.	0.07 in.
Rainfall at Upland	0.42 "	0 "	0 "	0 "	0.39 "	4.26 "	6.18 "	1.77 "	0.30 "	0 "	Tr.	0.07 "

FIG. 4.

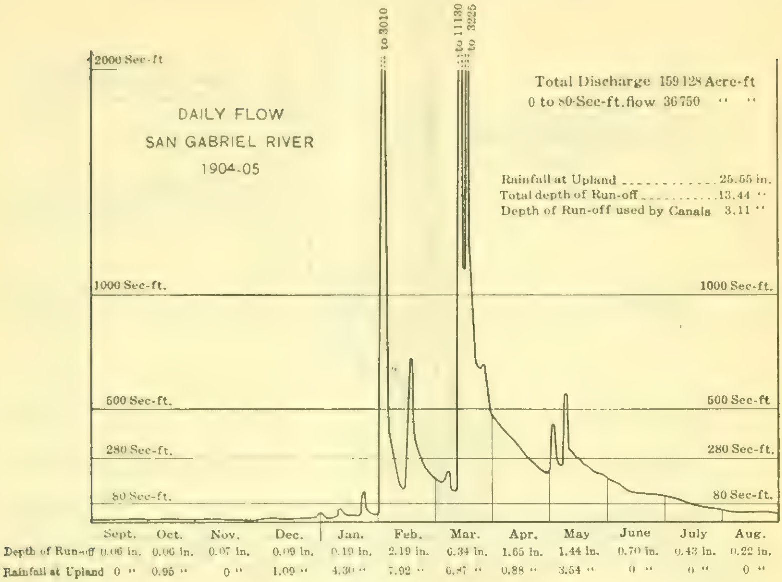

to 3010
to 11130
to 3225
2000 Sec-ft
DAILY FLOW
SAN GABRIEL RIVER
1904-05
Total Discharge 159 128 Acre-ft
0 to 80 Sec-ft. flow 36 750 " "
Rainfall at Upland .... 25.55 in.
Total depth of Run-off .... 13.44 "
Depth of Run-off used by Canals 3.11 "
1000 Sec-ft.
1000 Sec-ft.
500 Sec-ft.
500 Sec-ft
280 Sec-ft.
280 Sec-ft.
80 Sec-ft.
80 Sec-ft.
Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May June July Aug.
Depth of Run-off 0.06 in. 0.06 in. 0.07 in. 0.09 in. 0.19 in. 2.19 in. 6.34 in. 1.65 in. 1.44 in. 0.70 in. 0.43 in. 0.22 in.
Rainfall at Upland 0 " 0.95 " 0 " 1.09 " 4.30 " 7.92 " 6.87 " 0.88 " 3.54 " 0 " 0 " 0 "

FIG. 5.

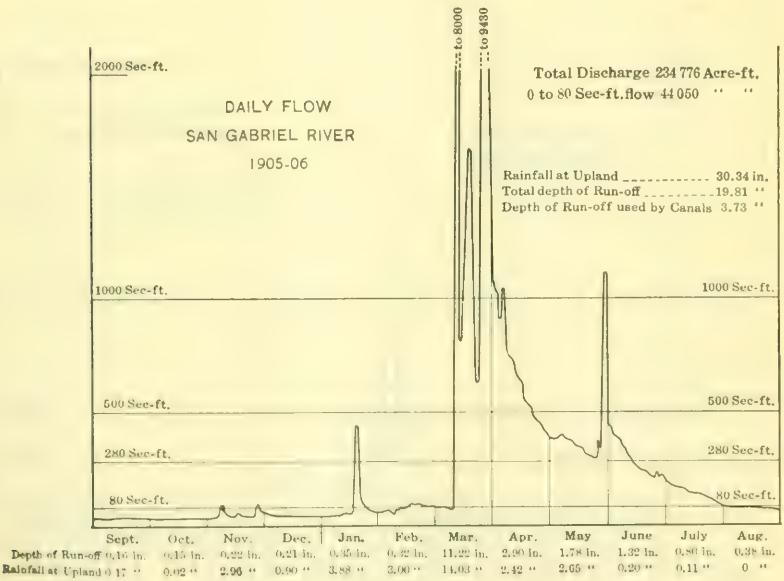
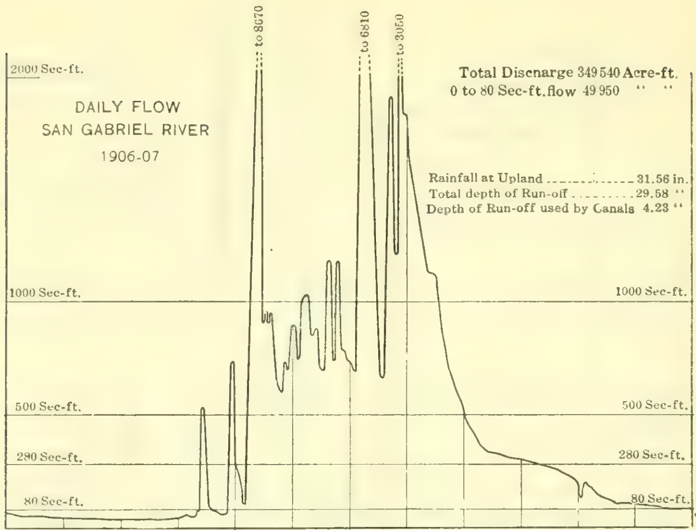
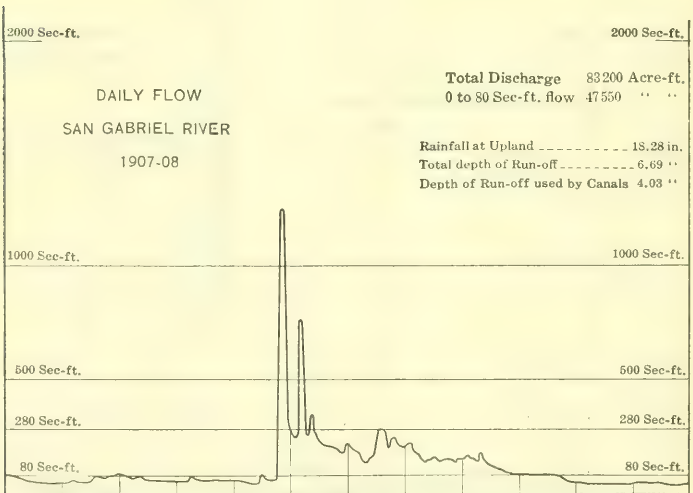

to 8000
to 9430
2000 Sec-ft.
DAILY FLOW
SAN GABRIEL RIVER
1905-06
Total Discharge 234 776 Acre-ft.
0 to 80 Sec-ft. flow 44 050 " "
Rainfall at Upland .... 30.34 in.
Total depth of Run-off .... 19.81 "
Depth of Run-off used by Canals 3.73 "
1000 Sec-ft.
1000 Sec-ft.
500 Sec-ft.
500 Sec-ft.
280 Sec-ft.
280 Sec-ft.
80 Sec-ft.
80 Sec-ft.
Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May June July Aug.
Depth of Run-off 0.16 in. 0.15 in. 0.22 in. 0.21 in. 0.35 in. 0.32 in. 11.22 in. 2.90 in. 1.78 in. 1.32 in. 0.80 in. 0.38 in.
Rainfall at Upland 0.17 " 0.02 " 2.96 " 0.90 " 3.88 " 3.00 " 14.03 " 2.42 " 2.65 " 0.20 " 0.11 " 0 "

FIG. 6.



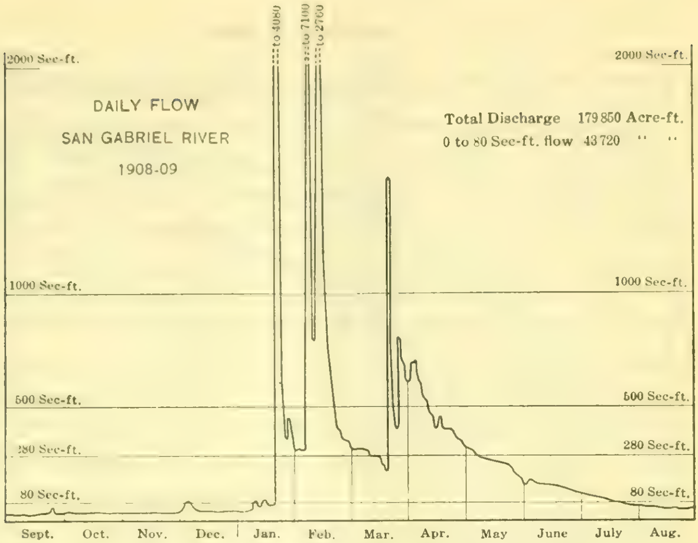
	Sept.	Oct.	Nov	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.
Depth of Run-off	0.24 in.	0.21 in.	0.20 in.	0.98 in.	4.92 in.	3.98 in.	9.76 in.	4.93 in.	1.82 in	1.27 in.	0.71 in.	0.46 in.
Rainfall at Upland	Tr.	0 "	0.75 "	9.10 "	9.71 "	3.19 "	7.32 "	0.53 "	0.12 "	0.84 "	0 "	0 "

FIG. 7.



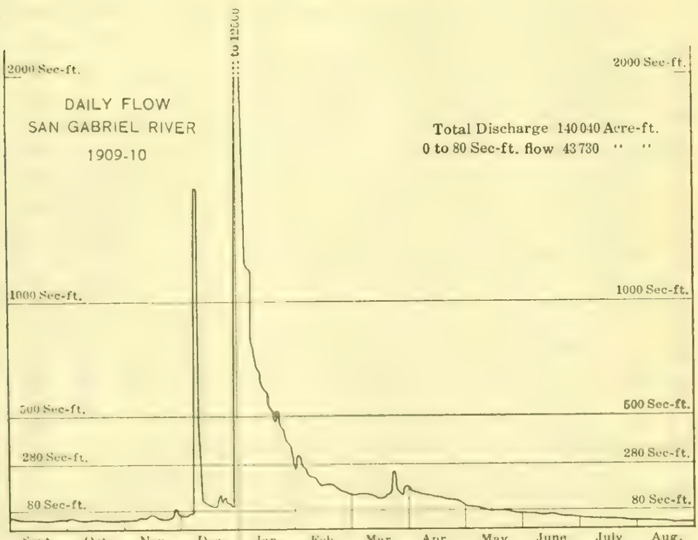
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.
Depth of Run-off	0.30 in.	0.35 in.	0.32 in.	0.30 in.	0.94 in.	1.26 in.	1.07 in.	0.78 in.	0.61 in.	0.35 in.	0.22 in.	0.19 in.
Rainfall at Upland	0 "	2.14 "	0.22 "	1.11 "	7.15 "	4.34 "	1.40 "	1.32 "	0.60 "	0 "	Tr.	0 "

FIG. 8.



	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.
Depth of Run-off	0.15 in.	0.17 in.	0.17 in.	0.24 in.	2.14 in.	5.02 in.	2.22 in.	2.36 in.	1.29 in.	0.72 in.	0.43 in.	0.26 in.
Rainfall at Upland	1.86 "	1.03 "	0.36 "	1.27 "	11.08 "	7.04 "	3.95 "	0.17 "	0 "	0 "	0.05 "	0.02 "

FIG. 9.



	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.
Depth of Run-off	0.20 in.	0.19 in.	0.24 in.	1.76 in.	5.47 in.	0.97 in.	0.81 in.	0.70 in.	0.43 in.	0.30 in.	0.21 in.	0.14 in.
Rainfall at Upland	0 "	0.36 "	2.33 "	11.41 "	2.83 "	0.56 "	2.35 "	0.20 "	0 "	0 "	0 "	0 "

FIG. 10.

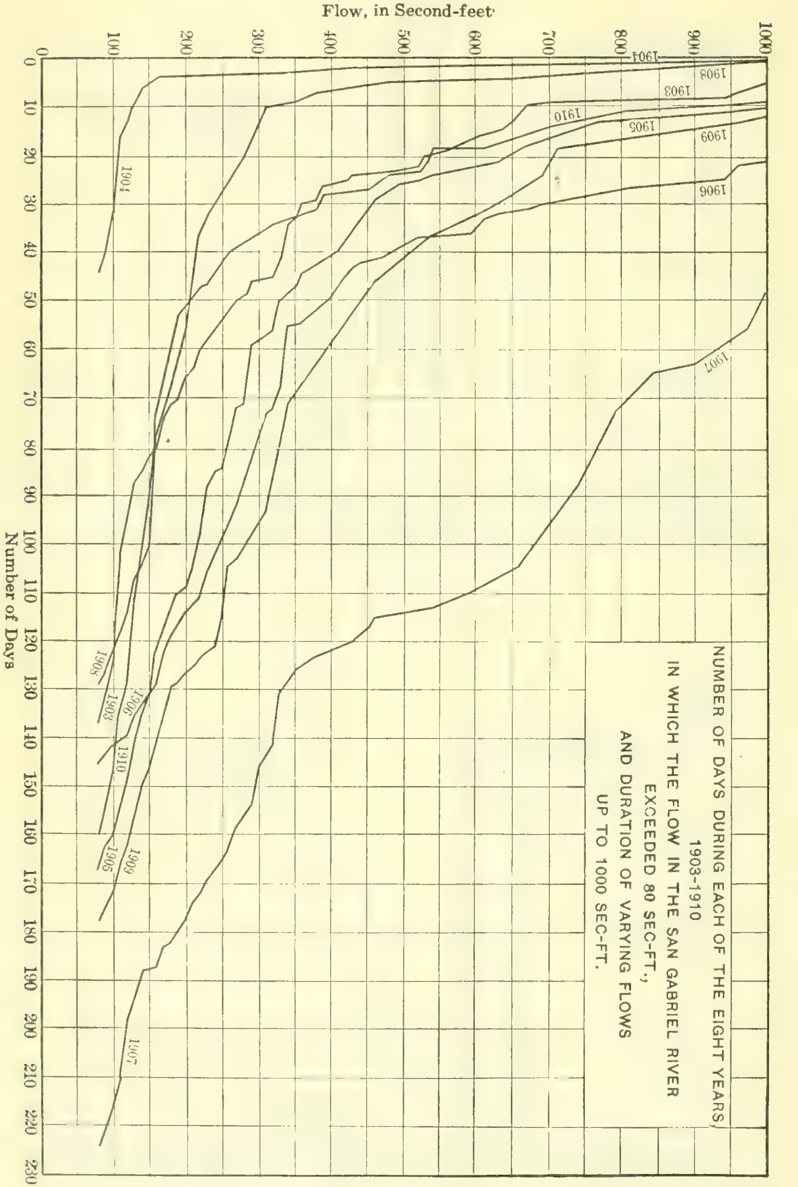

Flow, in Second-feet
Number of Days
NUMBER OF DAYS DURING EACH OF THE EIGHT YEARS,
1903-1910
IN WHICH THE FLOW IN THE SAN GABRIEL RIVER
EXCEEDED 80 SEC-FT.,
AND DURATION OF VARYING FLOWS
UP TO 1000 SEC-FT.
1903
1904
1905
1906
1907
1908
1909
1910

Fig. 11.

ground basin. The remainder is now waste water running into the Pacific Ocean.

It is difficult to determine the quantity of water entering the underground storage, as no exact measurements of the waste flow have ever been made. The principal factors governing it are the character of the material in the surface of the wash, the area covered by the stream, the velocity of the flow, the temperature of the water, and the quantity of suspended matter. All these factors will vary with the individual character of the different periods of flood flow. The late W. B. Clapp, M. Am. Soc. C. E., Hydrographer of the U. S. Geological Survey, made some measurements along this line in 1903, but did not consider them at all satisfactory. They showed a maximum absorption of 86 sec-ft. on May 23d, 1903, in the main river channel between the gauging station and the Narrows, where much of the surplus water of the underground storage of the San Gabriel Valley is forced to the surface. As pumping is used extensively in the valley, the greater part of the natural underground flow is now being put to use, and it must be taken into consideration in calculating the available supply for further economic use.

In the case of flood-water diverted from the natural channel for surface storage, it is to be presumed that it will be used for irrigation on territory tributary to the underground basin fed by the stream. All return water would flow into it and go to offset any losses caused by the diversion. The quantity of this return water is not determinable, but it is variously estimated at from 10 to 50% of the water used. Again, any diversion, even up to the maximum economic quantity, will still leave times when there is water flowing in the natural channel, and will simply shorten the time when there is water flowing in that channel. For these reasons it is not considered necessary for any such diversion to pass a large flow in order to maintain the existing conditions of the water supply of the underground basin. Where the diversion is for the purpose of increasing the underground storage, the conditions are somewhat different. The maximum storage possible should be obtained in the natural channel, and a considerable flow should be passed into it before any diversion is made.

During the rainy season of the majority of years there are one or more periods of a few days in which the flow runs into the thousands of second-feet. In these periods the flow is too great and the duration

too short to warrant handling by any diversion. That part of the total run-off of the San Gabriel River which is available for further economic use by storage, either surface or underground, is the flow in excess of 80 sec-ft. plus a reasonable allowance for water entering the underground basin, but not including the extreme floods.

For the purpose of determining this flow, there are available the records of the daily flow for the eight years, as shown on the hydrographs. The only way to test the reliability of any deductions drawn from these records, in relation to long periods of time, is by a comparison with the rainfall records which have been kept for a much longer time. This comparison will only apply to general conditions, for, though the stream run-off is dependent directly on the precipitation, the percentage showing as surface run-off varies greatly. Much depends on the general seasonal conditions and on the character of the individual storms. Fig. 12 illustrates some of the characteristics of the rainfall and run-off during these 8 years. It shows how greatly the percentage of the run-off depends on the conditions under which the rainfall comes. In the season of 1905-06 a few very heavy storms gave a large percentage of run-off, of which a great part was in extreme floods, while nearly the same rainfall in 1908-09, coming in a large number of smaller storms, gave a smaller total run-off with a larger quantity under moderate flood stages. Similarly, the season of 1904-05, with the precipitation falling on a dry water-shed, gave less run-off for all stages of flow. These are only a few of the factors which govern the quantity of run-off resulting from the precipitation of any given season. However, the general seasonal conditions of precipitation give some valuable information in regard to the possible supply for storage.

Fig. 13 is a diagram showing the rainfall for a number of Southern California points. Fig. 14 shows the seasonal rainfall of a number of places near the drainage area, expressed as percentages of excess or deficiency from the long-time mean. These diagrams show that the period from 1897 to 1900 was the dryest in 40 years, or the dryest in 60 years, if the San Diego records are of any value for comparison. This is as far back as the records extend, but early California history indicates that there was another period of that kind a little more than 100 years ago. This period might be taken into consideration as a limiting condition, but any short-time average, using the records

during that time, would give results which would be too low. The average rainfall from 1902 to 1910 is very near the long-time average, and the different seasons represent all but very unusual conditions. The season of 1903-04 had a very light rainfall and that of 1906-07 an unusually heavy one. Any conclusions drawn from the records of these eight seasons, except in abnormal cases, should cover the conditions to be met in the future.

AVERAGE RAINFALL FOR 7 FOOT-HILL STATIONS AND
DEPTH OF RUN-OFF FOR DIFFERENT DIVISIONS OF THE FLOW
SAN GABRIEL RIVER

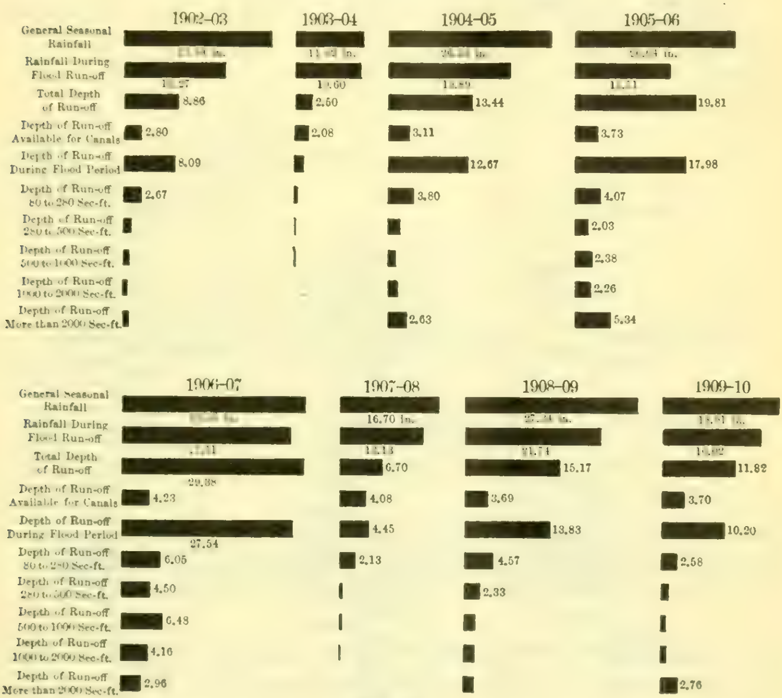


FIG. 12.

In calculating the available supply for surface storage, it is at once evident from the rainfall records that there are a large number of alternating seasons in which the run-off is comparatively small. Any large surface reservoir drawing its supply from a diversion of the flood flow would have to furnish the supply for more than one irrigation with each filling. In order to calculate the available supply for such a reservoir, it is necessary to select a period during which the run-off

represents a limiting minimum condition. Figs. 15 to 18 show the total discharge for the flood periods under consideration and the discharge which would have been available for varying diversion capacities. Fig. 19 shows the discharge curve for all flows up to 1 000 sec-ft. for the several seasons. During these eight years, the period from January, 1903, to October, 1904, gives the limiting minimum condition. The rainfall records indicate that, other things being equal, the supply available during this period, if used during two irrigation seasons, would have been greater than that which would have been available

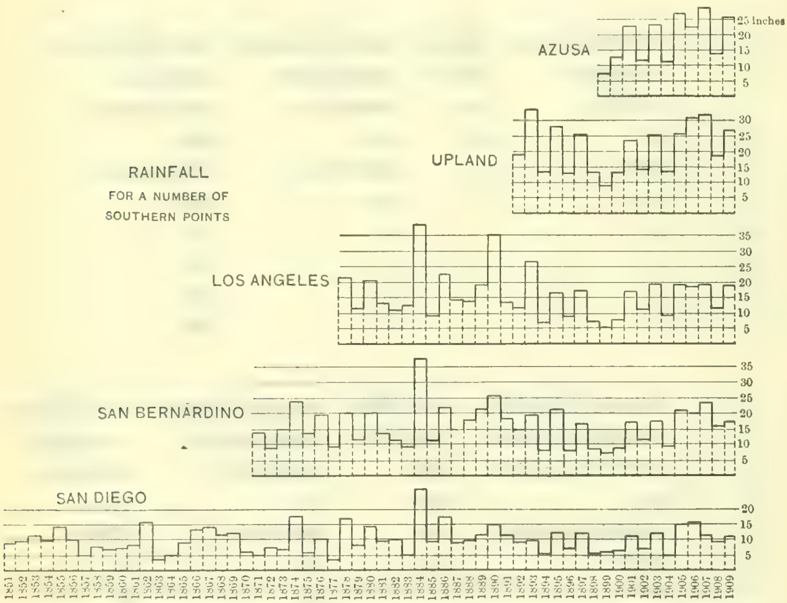


FIG. 13.

during any similar periods, including the seasons of 1872, 1873, 1882, 1883, 1899, and 1900. These seasons include 12% of the 40 years for which records are available, but in each of these years there would have been some storage water, in some of them probably enough for the half-reservoir capacity necessary for one irrigation season.

It was found, during the drought from 1897 to 1900, that practically every irrigation system in Southern California depending on a surface water supply was covering too great a territory for such a period. It was also shown that orchards could be kept alive for one or two years with very little water, the only loss being the crops for those seasons.


SEASONAL RAINFALL
DEPARTURES FROM THE MEAN
CLAREMONT Elev. 1200 ft.
Estimated Mean 18.85 in.
BEAR VALLEY DAM
Estimated Mean 30.22 in.
SIERRA MADRE Elev. 1400 ft.
Estimated Mean 25.74 in.
SAN BERNARDINO
Elev. 1054 ft.
Mean 15.97 in.
LOS ANGELES
Elev. 293 ft.
Mean 15.75 in.
NEWHALL
Elev. 1200 ft.
Mean 16.88 in.
Season
Deficiency
Excess
Per Cent

FIG. 14.

The increased cost of water for irrigation, if it should be considered necessary to hold enough in storage to cover such a period, would be much greater than the value of the lost crops. Also, the area of land

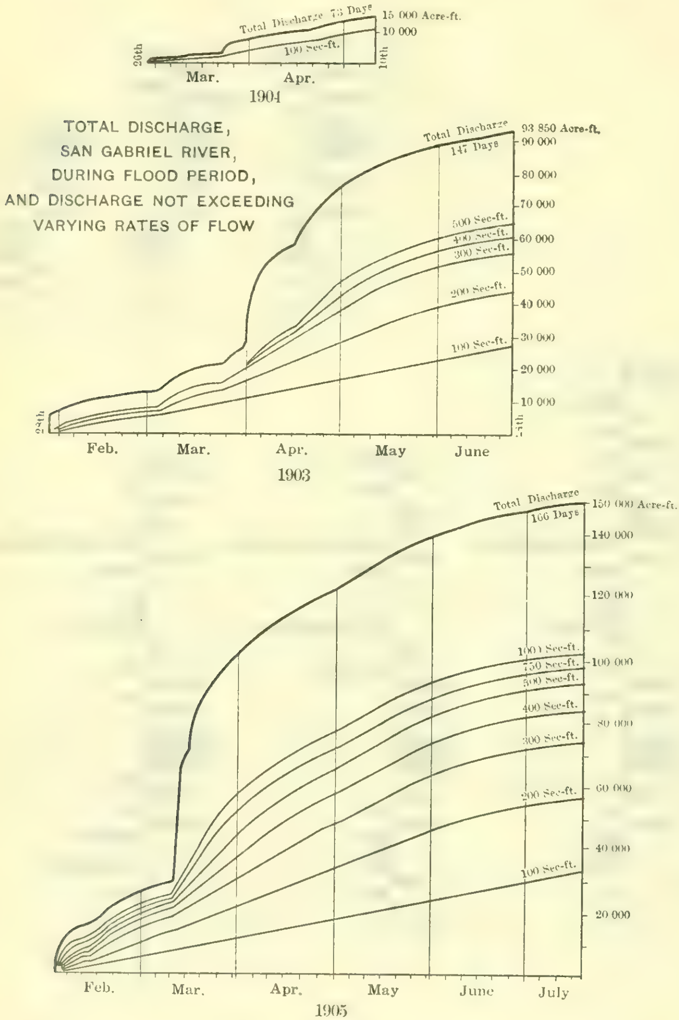


Fig. 15.

which could be placed under cultivation with the existing supply, and the resulting value of that supply, would have to be greatly reduced. Another point that must be taken into consideration is that there can

be a resort to pumping, even if at great cost, to cover short periods of deficient supply. For these reasons it is not thought necessary to consider extreme conditions for the economic minimum supply, and it is thought that the period from January, 1903, to October, 1904, may be taken as the limiting economic condition of the water supply which could be obtained by diversion of the flood-waters of the San Gabriel River for surface storage.

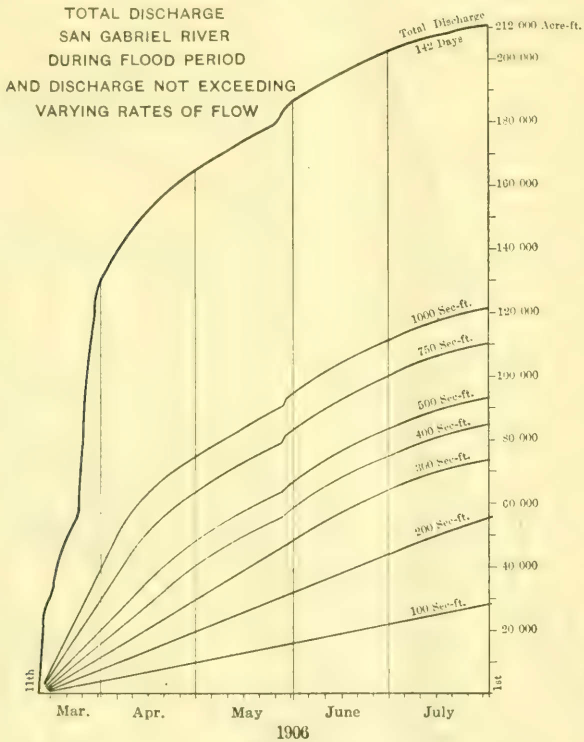


FIG. 16.

The limiting conditions with regard to the available supply for increasing the storage in the underground basins are somewhat different from those for surface storage. The slow movement of the underground waters tends to equalize the varying flows of the different years, and the great extent of the underground basins gives almost unlimited storage capacity. Where the present pumping draft is as great as the natural supply, or greater, the full capacity of these basins, above the limit of economic pumping, is available for in-

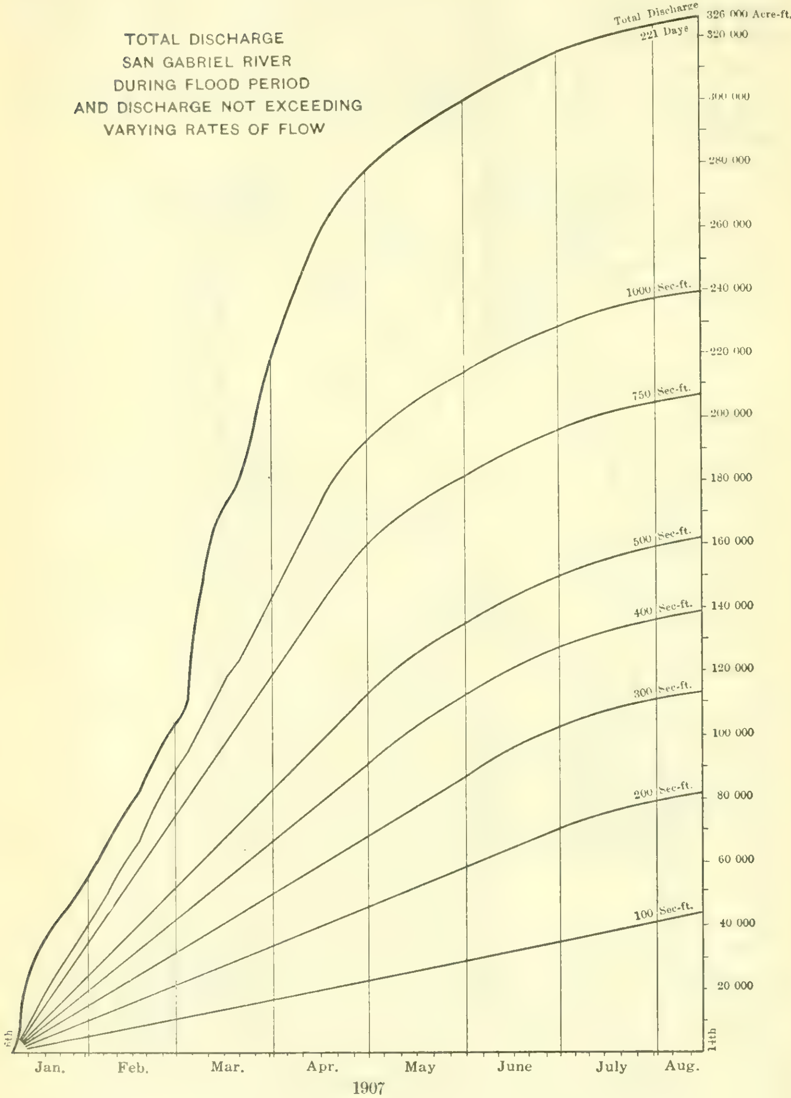

TOTAL DISCHARGE
SAN GABRIEL RIVER
DURING FLOOD PERIOD
AND DISCHARGE NOT EXCEEDING
VARYING RATES OF FLOW
Total Discharge
221 Days
326 000 Acre-ft.
320 000
300 000
280 000
260 000
240 000
220 000
200 000
180 000
160 000
140 000
120 000
100 000
80 000
60 000
40 000
20 000
1000 Sec-ft.
750 Sec-ft.
500 Sec-ft.
400 Sec-ft.
300 Sec-ft.
200 Sec-ft.
100 Sec-ft.
6th
14th
Jan.
Feb.
Mar.
Apr.
May
June
July
Aug.
1907

FIG. 17.

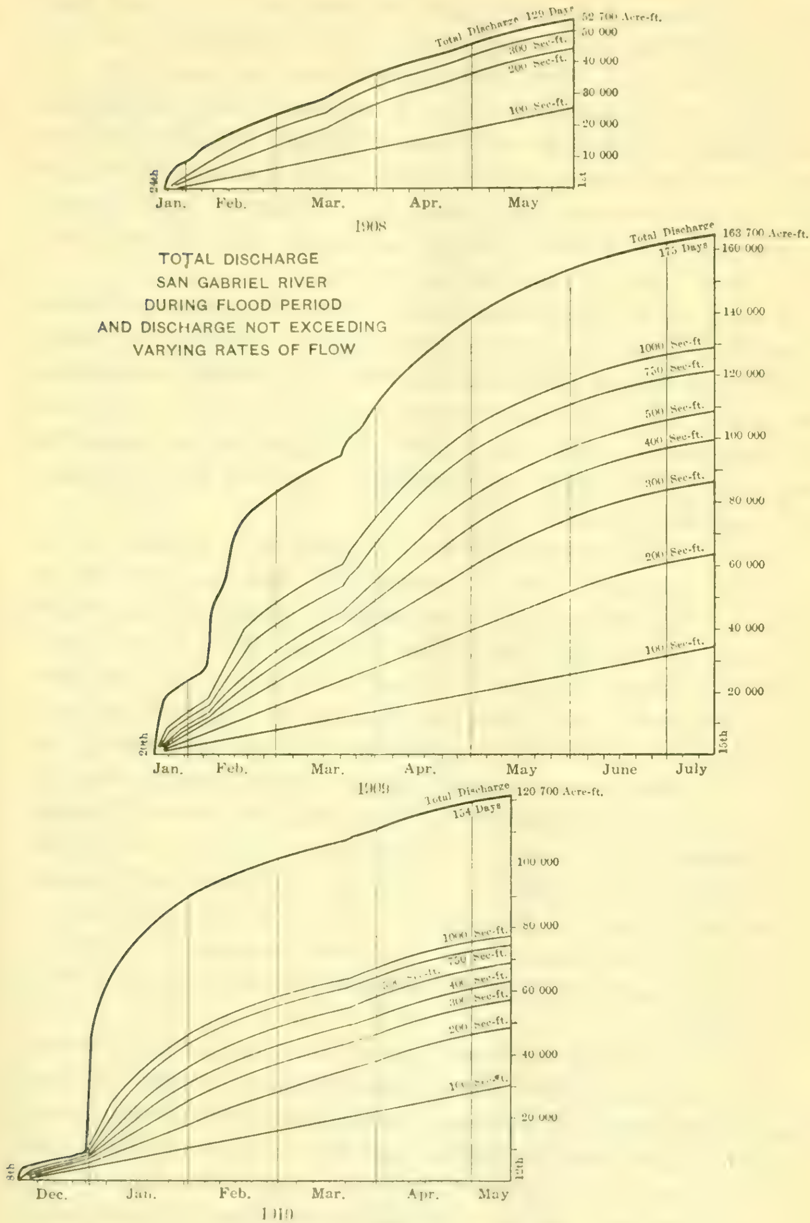

Total Discharge 129 Days
52 700 Acre-ft.
300 Sec-ft.
200 Sec-ft.
100 Sec-ft.
50 000
40 000
30 000
20 000
10 000
24th
1st
Jan.
Feb.
Mar.
Apr.
May
1908
TOTAL DISCHARGE
SAN GABRIEL RIVER
DURING FLOOD PERIOD
AND DISCHARGE NOT EXCEEDING
VARYING RATES OF FLOW
Total Discharge
175 Days
163 700 Acre-ft.
160 000
140 000
120 000
100 000
80 000
60 000
40 000
20 000
1000 Sec-ft
750 Sec-ft.
500 Sec-ft.
400 Sec-ft.
300 Sec-ft.
200 Sec-ft.
100 Sec-ft.
20th
15th
Jan.
Feb.
Mar.
Apr.
May
June
July
1909
Total Discharge
154 Days
120 700 Acre-ft.
100 000
80 000
60 000
40 000
20 000
1000 Sec-ft.
750 Sec-ft.
400 Sec-ft.
300 Sec-ft.
200 Sec-ft.
8th
12th
Dec.
Jan.
Feb.
Mar.
Apr.
May
1910

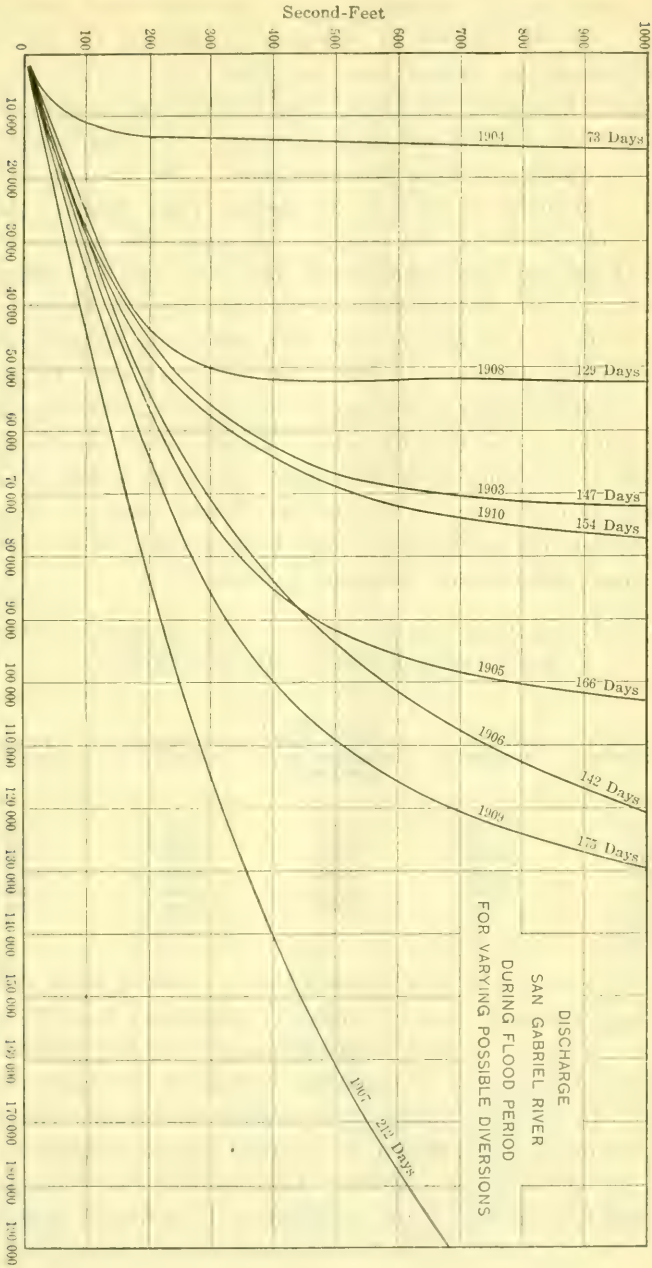
FIG. 18.

creased storage. The ultimate supply available is the total flood run-off of the maximum year; but, as the cost of spreading the water or delivering it to shafts and galleries would be considerable, the economic limit is where the value of the stored water will warrant the expense of obtaining the storage. Although this will vary with each individual case, as a general average, this limiting condition is taken as the maximum supply which can be relied on for an average of one year out of three. In this case, again, short periods of extreme flood cannot be considered as available.

For the eight years under consideration, the season of 1908-09 meets this condition for the San Gabriel River. The rainfall records show that in 30% of the 40 years for which such records are available, the rainfall was greater than for that season, and for 70% it was less. It would seem probable that, if the flow records for the seasons for which the rainfall records were available, this season would still meet this limiting condition.

The measured run-off of the San Gabriel River shows that, for the period from January, 1903, to October, 1904, there were 210 days in which the flow was more than the 80-sec-ft. capacity of the present diversions. During that time a little more than 76 000 acre-ft. passed by these diversions and down the wash in the valley. Of this quantity 46 000 acre-ft. could have been handled by a diversion having a capacity of 500 sec-ft. During these two seasons, there were 57 500 acre-ft. available for the present canals with the 80-sec-ft. capacity. Similarly, during the season of 1908-09, nearly 136 000 acre-ft. passed the diversion point of the present canals in 175 days, with 81 500 acre-ft. available for a 500-sec-ft. diversion. During the entire season, 44 000 acre-ft. were available for the canals. If it were possible to obtain storage for this water at an expense warranted by its value, it would be possible to double the area now irrigated from the surface flow of the river.

The ratio between the capacity of the diversion and the discharge through it during the flood season is much smaller for large diversions than for small ones. In the case of surface storage, the diversion canal would be a large factor in the total cost, and, in increasing the underground storage, the number of basins or shafts and galleries would be one of the main factors. The size of the diversion which would give a discharge warranting the expense of the storage is a matter



Acre-Feet
FIG. 19.

which would have to be worked out in connection with some special project. For the purpose of obtaining an idea of the possibilities of such storage, two assumed cases are given.

The first assumes that a basin in the foot-hills can be converted into a storage reservoir, and that the flood-waters of the San Gabriel River can be brought to it by a diversion canal. The limiting minimum supply is assumed as that for the period from January, 1903, to October, 1904, covering two irrigation seasons. The loss by evaporation and seepage is assumed to be 25%, the duty of water to be 2 acre-ft. per acre, and the value of the water right as $1 000 per inch of annual flow. It is also assumed that, besides the 80-sec-ft. capacity of the existing diversions, a flow of 20 sec-ft. is passed to meet any possible ultimate losses in the supply for underground storage or prior water rights; that is, that no water is diverted until the flow is more than 100 sec-ft., and, when it is more than that, a flow of at least 20 sec-ft. is maintained in the natural channel below the diversions. The details of the results which could be obtained by such a diversion, under these assumptions, are given in Table 1.

TABLE 1.—RESULTS OF POSSIBLE FLOOD DIVERSIONS FROM THE SAN GABRIEL RIVER FOR SURFACE STORAGE.

Diversion, in second-feet.	Discharge, in acre-feet.	Quantity available for irrigation, in acre-feet	Area irrigated, in acres.	Value of water right.
100	17 700	13 275	3 320	$454 840
200	30 100	22 575	5 644	773 223
300	37 300	27 975	6 994	958 178
400	42 260	31 695	7 924	1 085 588
500	46 180	34 635	8 659	1 186 283
750	48 500	36 375	9 094	1 245 878

In the second case it is assumed that a series of pools, connected with shafts and galleries, each capable of absorbing a flow of 50 sec-ft., is to be constructed to take the flood-waters of the San Gabriel River. The flow taken for the computations is that of the single season of 1908-09. In order to increase the present underground storage, the present water level would have to be raised and the overflow from the low points of the basin increased. It is assumed that this and other losses will take up 50% of the increased supply delivered to the underground basin. Some of the water stored in the season under con-

sideration, and in years when the flow is greater, will have to be used to equalize the deficiency of the dryer years. It is assumed that two-thirds of the water which could be stored during this season would be available for pumping during any one season. The duty of water, as before, is assumed to be 2 acre-ft. per acre. The value of the additional water stored in this way is very difficult to estimate. Under general conditions, the cost of pumping is greater than the cost of maintenance of the distributing system from a surface supply, and the capital invested is less. In this case, as an increase in the underground storage would result in the irrigation of lands now of little value, and would make them of great value, it is assumed that the value of the net available increased storage is the same as that for surface storage, that is, $1 000 per inch for the water right. Besides the present diversion of 80 sec-ft., it is assumed that a flow of at least 100 sec-ft. is to be maintained in the natural channel whenever possible, in order to assure the maximum absorption in that channel. With these assumptions, the details of the different possible diversions are given in Table 2.

TABLE 2.—RESULTS OF POSSIBLE FLOOD DIVERSIONS FROM THE SAN GABRIEL RIVER FOR UNDERGROUND STORAGE.

Diversion, in second-feet.	Discharge, in acre-feet.	Quantity available for pumping, in acre-feet.	Area irrigated, in acres.	Value of water right.
50	12 460	4 153	2 077	$284 549
100	23 420	7 806	3 903	434 711
150	31 920	10 640	5 320	728 840
200	38 240	12 747	6 374	873 238
250	43 360	14 453	7 227	990 099
300	47 600	15 867	7 934	1 086 956
350	51 300	17 100	8 550	1 187 350
400	54 500	18 167	9 084	1 244 508
450	57 220	19 073	9 537	1 306 569
500	59 620	19 873	9 937	1 361 569

The general value of $1 000 per miner's inch for water rights scarcely gives a fair idea of the local conditions in the San Gabriel Valley. At the current rate of 2 cents per inch per hour delivered at the groves, the annual charge per inch is about $175, or 7% of $2 500. This, calculated in acre-feet, gives a warranted investment of $171.23 per acre-ft., including both storage and distributing system, for the net available stored water, and would warrant the construction of very extensive storage systems.

There are many small streams in Southern California having a run-off which is similar to that of the San Gabriel River, and the only way to get any idea of the available supply for storage from them is by comparison with it. The rainfall on their drainage areas is about the same. It is probable that the run-off per square mile from them is greater than for the average of the total drainage area of the San Gabriel River, and that a larger percentage of it comes in extreme floods. However, it would be possible to handle economically a larger part of the floods from the smaller streams. Under the assumptions given in the two cases worked out, a diversion capacity of 2.25 sec-ft. per sq. mile of drainage area will assure sufficient supply for a reservoir storage of 200 acre-ft. for each square mile, irrigating 40 acres. At 2 cents per inch per hour this would warrant an expenditure of $13 250 per sq. mile of drainage area. In the same way, there would be available for increasing the underground storage a supply sufficient to irrigate 45 acres.

In many places where irrigation is developed extensively, the conditions of run-off are similar to those in the San Gabriel Mountains. Except in a few places where large natural storage basins have been found on the streams, there is a large waste flood flow. As the value of the land and crops increases, the possibility of obtaining more storage increases. Much remains to be done to secure the maximum possible use of the water supply of almost all irrigated districts.

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PAPERS AND DISCUSSIONS

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THE USE OF CEMENT FOR EXCLUDING WATER FROM OIL SANDS IN DRILLING WELLS.*

By Paul M. Paine, Assoc. M. Am. Soc. C. E.

In connection with the drilling of oil wells, cement is being used in increasing quantities for excluding from the oil sand the water in strata nearer the surface. This water, if not prevented from going down into the oil sand, will displace the oil, because of its greater specific gravity, and eventually ruin the well. Unfortunately, the damage does not end here, for experiences in the older fields have shown that this flooding of the oil sand spreads gradually over wide areas, depending mainly on the porosity of the sand and the gravity of the oil, and, unless checked in some manner, it will ruin neighboring wells. For this reason the encroachment of water into the oil-bearing strata is a serious problem in any oil-field, and is particularly difficult to overcome where the water strata are directly above or below the oil-bearing sand.

The mechanical difficulties and expense connected with this problem have led careless operators to take long chances at times, and, in many of these cases, where the work has not been successful, there has been serious injury, not only to such wells, but also to adjoining properties. A measure of State relief has been obtained in some States where laws have been passed requiring operators to remedy

*This paper will not be presented at any meeting, but written communications on the subject are invited for publication with it in *Transactions*.

such defects, but it is generally agreed that the only permanently satisfactory method is to shut off the water effectually at the time the well is being drilled and before the hole has been carried into the oil sand.

The development of deep drilling, which has come with the introduction of the use of casing, has seen marked advances in methods, and it is not unusual to finish wells with a 6-in. hole at a depth of 4 000 ft. or more. In such wells several "strings" of pipe may be used, the first and largest being carried down from the surface until it is "landed" at a suitable depth, or until it is "frozen" by caving material falling in against it from the walls of the hole and binding it so that it cannot be moved farther, either up or down. The next "string," the collars of which will run inside of the first one, is then put in, and drilling is continued until this second string is either landed or frozen, and so wells frequently contain strings of 15½-in., 70-lb., 12½-in., 40-lb., 10-in., 40-lb., 8-in., 28-lb., 6¼-in., 20 or 26-lb., and 4½-in., 12½-lb., lap-welded, screw casing. At the bottom of each of these strings there is a shoe with an outside diameter slightly greater than that of the pipe collars, so that, as the pipe is lowered, the collars will be sure to pass through any opening through which the shoe has passed.

Preventing the water from reaching the oil is effected by landing a tight string of pipe, called the "water string," at a level known to be below the lowest water stratum and above the oil sand. This is done before the hole is drilled into the latter, and, wherever possible, the water string is landed on a "shell," the general oil-field term for any hard compact rock. This is illustrated in Fig. 1. In some fields all that is necessary is to stop drilling and drive the pipe into this shell; the well is then baled dry, and, after standing a day or two, a baler is run in to ascertain whether or not the pipe is holding the water back. If water has come in, it means that the bond between the casing shoe and the shell is not tight, or that the casing leaks. The cause of the leakage may be determined by special devices, and then a suitable remedy may be applied. Often, however, a hard shell in which to land the casing cannot be found, and the pipe is stopped when the shoe is in some soft measure such as shale. In either case, it frequently happens that wells which have shown a satisfactory water test at the time of drilling, have developed water later, due to

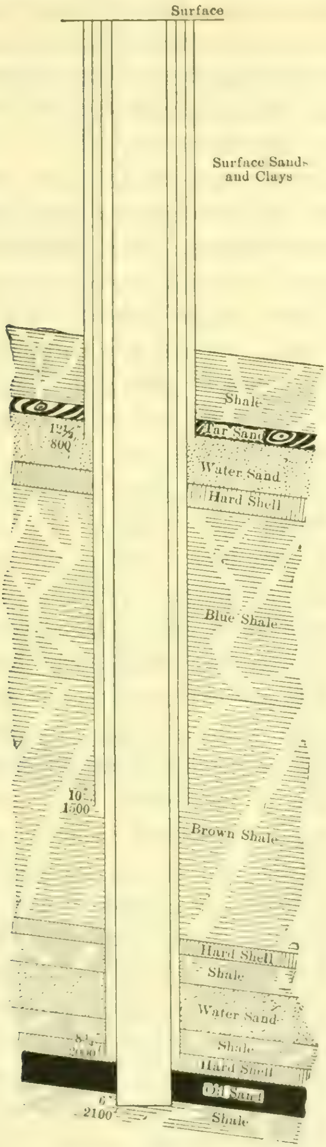
Surface
Surface Sands and Clays
Shale
Tar Sand
12½"
800'
Water Sand
Hard Shell
Blue Shale
10"
1500'
Brown Shale
Hard Shell
Shale
Water Sand
Shale
Hard Shell
Oil Sand
6"
2100'
Shale

FIG. 1.

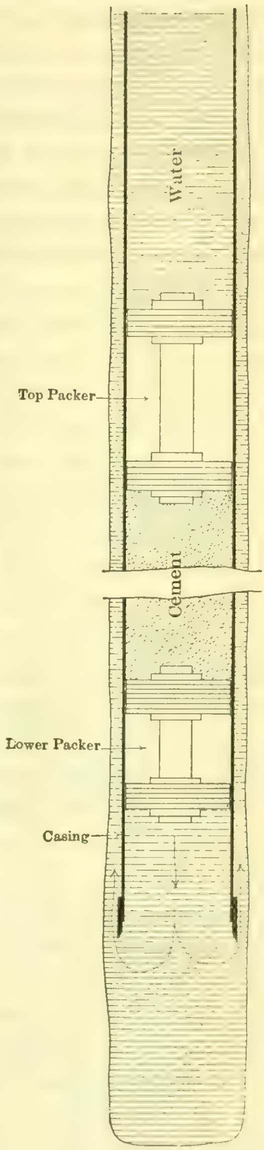
Water
Top Packer
Cement
Lower Packer
Casing

FIG. 2.

gradual leaching through the interstices of surrounding porous measures. This uncertainty led to the search for a more thorough method of sealing off the water, and the use of cement has come to be recognized as the only positive remedy. The problem, then, is one of placing from 2 to 8 tons of cement between the casing and the wall, at the bottom of holes ranging in depth from 600 to 4 000 ft.

In all the methods described herein, when the hole has reached the desired depth at which to cement, it is reamed out wider for 60 or 70 ft. above the bottom with an under-reamer, a tool which widens the hole with cutting lugs that spring out when lowered below the casing shoe. This gives additional room for the cement and insures a better bond. The hole is also cleaned of mud and cuttings, and fresh water is run in. The simplest method of placing the cement is that known as "baling" it in. The hole is filled with water to the top of the casing, and the latter is raised until the shoe is 10 or 12 ft. from the bottom. The cement, mixed to a thick grout, is then run in in a specially devised baler which dumps when it reaches the bottom. When from 1 to 2 tons (dry weight) have been placed in this way, a plug is screwed into the casing collar at the top, and the casing is lowered. As the casing is full of water, the weight of the pipe forces a large portion of the cement out into the formation and up between the casing and the wall of the hole, as the casing shoe is lowered to the bottom. As a final precaution, the casing is driven, in order to force the shoe into the bottom as far as possible. Instead of using a baler, some operators prefer to run in the cement in a series of long narrow bags tied to the bottom of the drilling tools; when the bottom is reached, a few strokes of the tools loosen the bags and break them up so that the cement is freed. In connection with these methods the patented Baker "cement plug" is sometimes used instead of the one screwed into the top of the casing before it is lowered. This plug is of light cast iron, made so that it may be hung from the baler with soft rope and run down inside the casing. When lowered below the casing shoe and then raised with a slight tension, a set of clips catch on the shoe, and the bottom opening of the casing is effectually closed. The casing is then lowered, the cement is forced up on the outside, and the baler is loosened by a stronger pull which breaks the soft rope. The plug, being of cast iron, is easily drilled up.

A method of particular value in very deep wells, or in those in which the water string tends to "freeze" unless moved at frequent intervals, is that known as the disk method, in which patented packers are used. This requires that a "circulation" be obtained, that is, that there be a free passage for fluid pumped down inside the pipe to come to the surface on the outside. In order to obtain this, a 10 by 5 by 12-in. pump of the type used in the oil-fields for pumping mud in drilling wells with the rotary system, is set up and connected to the casing head with a section of 2½-in. pressure armored hose, as shown in Fig. 3. It is frequently necessary to work up to a pressure of several hundred

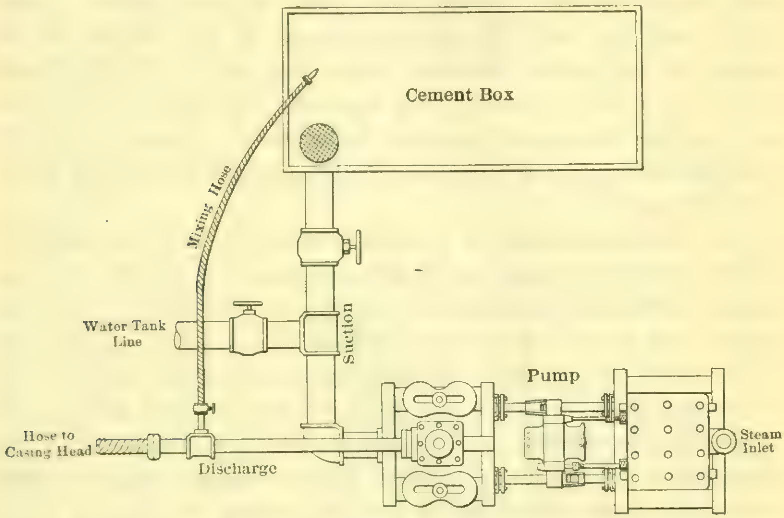

Fig. 3.

pounds before the fluid will create a passage on the outside of the pipe from the casing shoe to the surface. When this circulation has been obtained, the casing is suspended so that the shoe is 4 or 5 ft. from the bottom and enough fresh water is pumped in to insure a thorough cleaning of the bottom. The packers are of wood or of cast iron, and have heavy canvas or rubber washers which fill the space inside the casing, as shown in Fig. 2. The lower one is about 3 ft. long, and, after it has been placed in the casing, the pump suction is connected with the box in which the cement has been mixed just thin enough to pump readily. The cement is then pumped in against the lower packer, forcing it down until the cement box is drained; the top

packer follows, and water is then pumped in against the latter, pushing the combination of lower packer, cement, and top packer down the pipe. When the lower packer passes the casing shoe, it falls to the bottom of the hole and permits the cement to pass around the shoe and up on the outside of the casing. The top packer is of such length that when it has forced the cement out of the pipe and it strikes the lower packer, its top set of washers will not have passed out of the casing, and, as it cannot move farther, it will raise the pressure inside the casing and stop the pump. The casing is then landed on the bottom, the cement has been placed outside of the pipe at the bottom of the hole, and the packers, like the cement plug, are easily drilled up after the cement has set. The main objections to this method are the danger of the packers sticking while going down inside the casing and the fact that the lower packer may fall to the bottom in such way as to prevent the casing shoe from being landed squarely on the bottom, and thus get under it so that the bond is broken when the packer is drilled up.

The following method is in more general use, as it has seemed to secure better results and has no patented features: In this, as in the packer method, the principle of pumping in the cement under conditions that force it up on the outside of the casing is used, but this is done with an extra string of small pipe, usually 2½-in. tubing, which is lowered inside of the casing. After the hole has been drilled to the desired depth, reamed, and a circulation obtained, the casing is suspended with its shoe about 6 or 8 ft. from the bottom; the hole is filled with water to the top of the casing, and a string of tubing is run in until its bottom is slightly above the casing shoe. The packing head, shown in Fig. 4, is screwed into the casing collar at the top, and the gland in this head acts as a stuffing-box around the tubing. Then, with the casing full of water, when water is pumped in through the tubing, its only course is up on the outside of the casing. The surface arrangement for the pump is similar to that for the packer method (Fig. 3). On the bottom of the tubing has been placed either a bushing or a swedge nipple, reducing the opening from 2½ to 2 in. First, fresh water is pumped into the tubing, and this is followed with the cement grout; as soon as the cement is all in, the plug in the tubing tee above the packing head is unscrewed, and a wooden plug with a washer on it is dropped in on the cement. The tubing plug is then

replaced, and water is pumped in against the wooden plug, chasing the column of cement down the tubing. The water in the casing is incompressible, and the cement must travel around the shoe and up on the outside. The purpose of the swedge nipple at the bottom of the tubing is to show when the cement has passed out. The plug is stopped, and the pressure on the gauge at the pump goes up. The casing is then lowered to the bottom, and the tubing is pulled out as rapidly as possible so that whatever cement has remained inside the casing may be baled out before it has had time to set. The cement is then allowed from 10 to 20 days in which to set, after which the well is drilled a few feet ahead of the shoe and then baled dry. If no water has come in at the end of a 24-hour period, it shows that the work has been successful, and drilling operations are resumed.

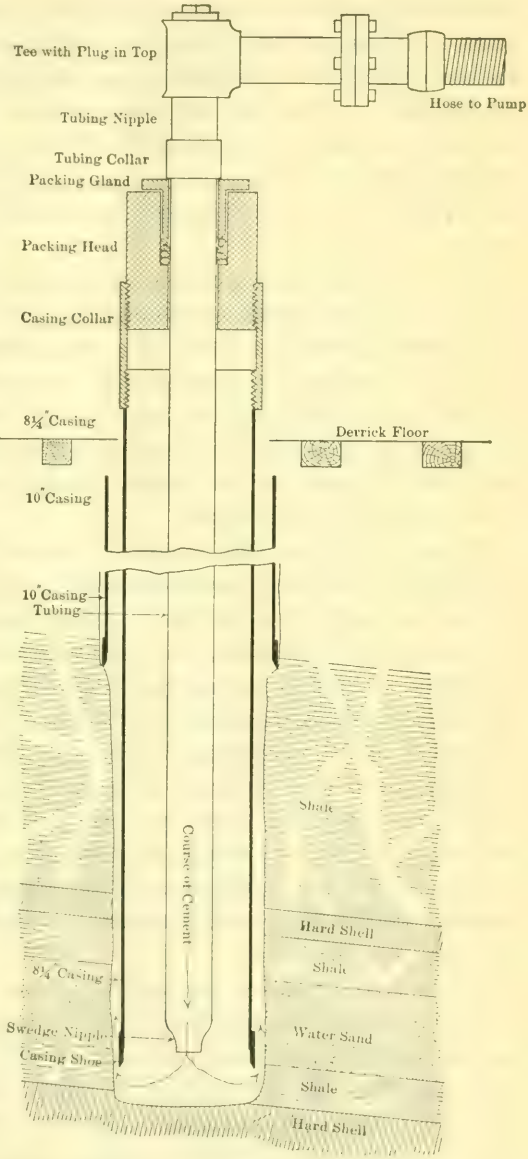

FIG. 4.

In one well cemented by the writer, a still lower water sand was encountered. Back of a string of 8-in., 28-lb. casing, $2\frac{1}{2}$ tons of cement had been placed, and as it was desired to shut off all the water with the 8-in. string and use a 6-in. string to finish the well, the former was cut off about 200 ft. from the bottom and the hole was re-drilled off to the side of the 8-in. pipe left in the old hole. This is known as "side-tracking," and the new hole goes off to the side of the old pipe and down directly beside it. This gave an opportunity to learn how far up, on the outside of the casing, the cement had set, and it was found to be 65 ft.

In the preliminary operation of securing a circulation, the fluid may come to the surface on the outside of the pipe, even though it is not coming around the shoe, if a leak exists in the casing. This may be determined by continuing to pump and lowering the casing to the bottom of the hole; if there is a leak, the circulation will continue; if the circulation has been entirely around the shoe, then when the latter is placed on the bottom, the fluid will be held in and the pump pressure will be raised.

From 2 to 6 tons (dry weight) of cement are generally used, depending on conditions; and even larger quantities are inserted where an unusual cavity is to be filled. Before being mixed with water the cement should be screened, and particular care should be taken that no pieces of bags or strings get into the suction line. Preferences for different brands of cement are found in different localities, but there appears to be little advantage in any one kind of cement, if the time of initial set is long enough to cover the period of mixing and pumping it, and of lowering the casing. Sand should not be mixed with the cement, and the grout should be given every opportunity to set; for this reason the hole should be made as free from mud, oil, and gas as possible, the latter especially tending to prevent the set by keeping the cement in motion.

It sometimes happens, particularly in new territory, that after the oil sand has been penetrated and the well is being drilled still deeper, another water sand is encountered, known as "bottom" water. Under such conditions, in the presence of active quantities of oil and gas, the work becomes more difficult. The most effective method is to pull up the casing until the shoe is a short distance below the bottom of the oil sand, and then build a "bridge" in the hole below the shoe by

running in broken pieces of brick and common manila rope. This bridge closes the hole and forms a landing place for the casing shoe after the cement has been run in. More care in gauging the quantity of cement to be placed is necessary in this case, in order that none of it may reach the oil sand and clog it, thereby tending to interfere with the oil production.

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THE PREWITT RESERVOIR PROPOSITION.*

By J. C. Ulrich, M. Am. Soc. C. E.

To be Presented September 17th, 1913.

The Prewitt Reservoir Proposition was conceived and developed by the Great Western Sugar Company for the purpose of increasing the effective water supply of the lower South Platte Valley, in the vicinity of Sterling. This Company, strictly speaking, is not engaged in the business of promoting irrigation propositions, but in the manufacture of sugar from beets. Though the promotion of irrigation propositions is not, in itself, one of its functions, it has a very definite indirect interest in the effectiveness of the water supply of the regions in which it operates.

Farmers will not raise beets, except at a profit, and beet culture cannot be conducted at a profit to the producer, except in regions in which a certain supply of water is available for use well into September.

This Company owns and operates three important sugar factories in the valley of the South Platte River: At Sterling, at Brush, and at Fort Morgan. The combined daily capacity of these plants, during the sugar-making campaign, is nearly 3 000 tons. In order that their operation may be profitable, it is necessary that they be supplied with a sufficient tonnage of beets to keep them running at least 100 days during each season. This requires about 300 000 tons of beets.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

* A paper read before the Colorado Association of Members of the American Society of Civil Engineers, on January 11th, 1913

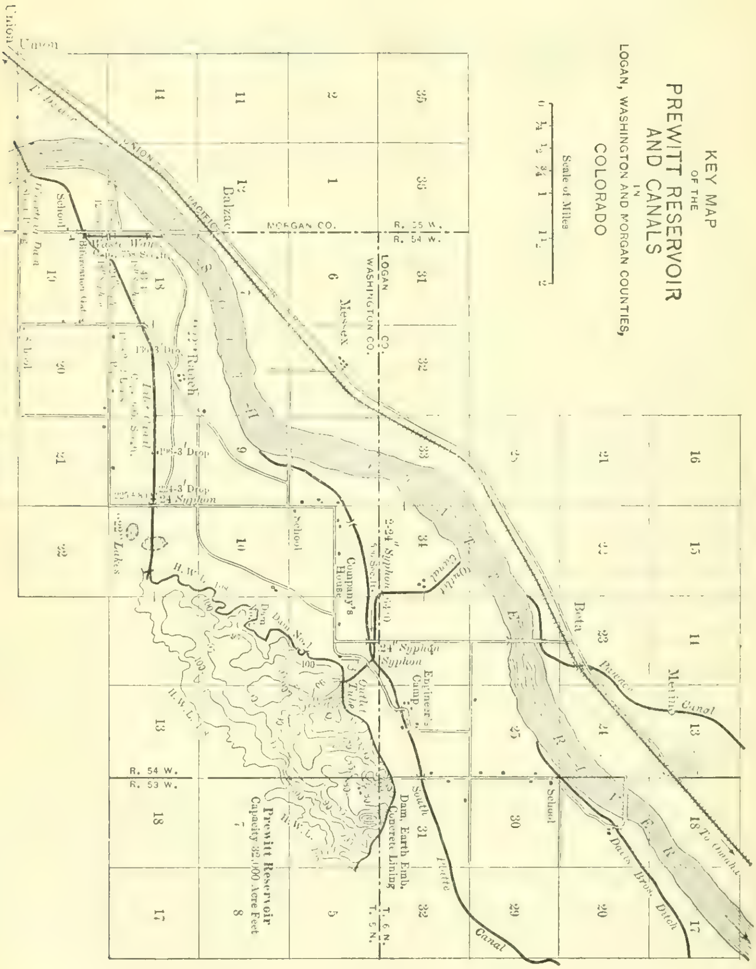
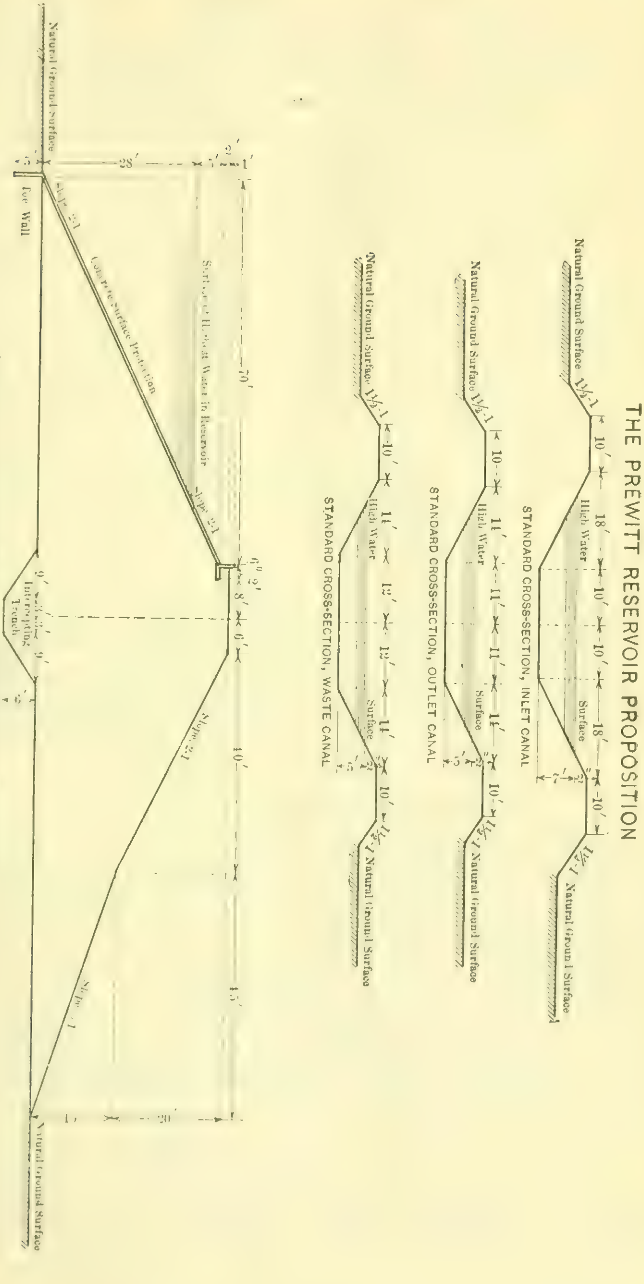

KEY MAP
OF THE
PREWITT RESERVOIR
AND CANALS
IN
LOGAN, WASHINGTON AND MORGAN COUNTIES,
COLORADO
Scale of Miles
MORGAN CO.
LOGAN CO.
WASHINGTON CO.
R. 55 W.
R. 54 W.
R. 53 W.
T. 6 N.
T. 5 N.
Balzac
Messex
Beta
School
Company's House
Engineer's Camp
Outlet Tube
Dam No. 1
South Platte Canal
Davis Bros. Ditch
Pawnee Canal
To Omaha
Prewitt Reservoir
Capacity 32,000 Acre Feet
Dam, Earth Emb.
Concrete Lining
Lakes

FIG. 1.



STANDARD CROSS-SECTION OF RESERVOIR EMBANKMENT
SHOWING CONCRETE PROTECTION ON WATER FACE AND INTERCEPTING TRENCH

FIG. 2.

After these sugar plants were constructed, it was found that, in some years, the water supply was not sufficient, during the later part of the growing season, to effect a full yield of beets; the result was that the supply of the latter was reduced, and the operating time of these factories was curtailed to a period which was too short to give a profit from their operation. In one season, it was even found necessary, on this account, to close one of the factories entirely.

The enforced idleness, throughout an entire season, of a plant representing an investment of nearly $1 000 000, is not a proposition to be viewed with equanimity, and, in order to lessen the probability of its recurrence, the Sugar Company conceived the idea of adding to the effective water supply by the creation of an additional plant for the storage and conservation of the water supply existing but not yet made available for the requirements of this region.

The Prewitt Reservoir Proposition contemplates the storage, and conservation for use in the latter part of the growing season, of about 32 000 acre-ft. of water, in addition to that which has been heretofore available.

This proposition has been conceived, financed, and developed by the Great Western Sugar Company, and has been delivered to the Iliff and the Logan Irrigation Districts, practically at the actual cost of construction of the works; the Company, in reimbursement for its expenditure, accepting the bonds of the two districts at par.

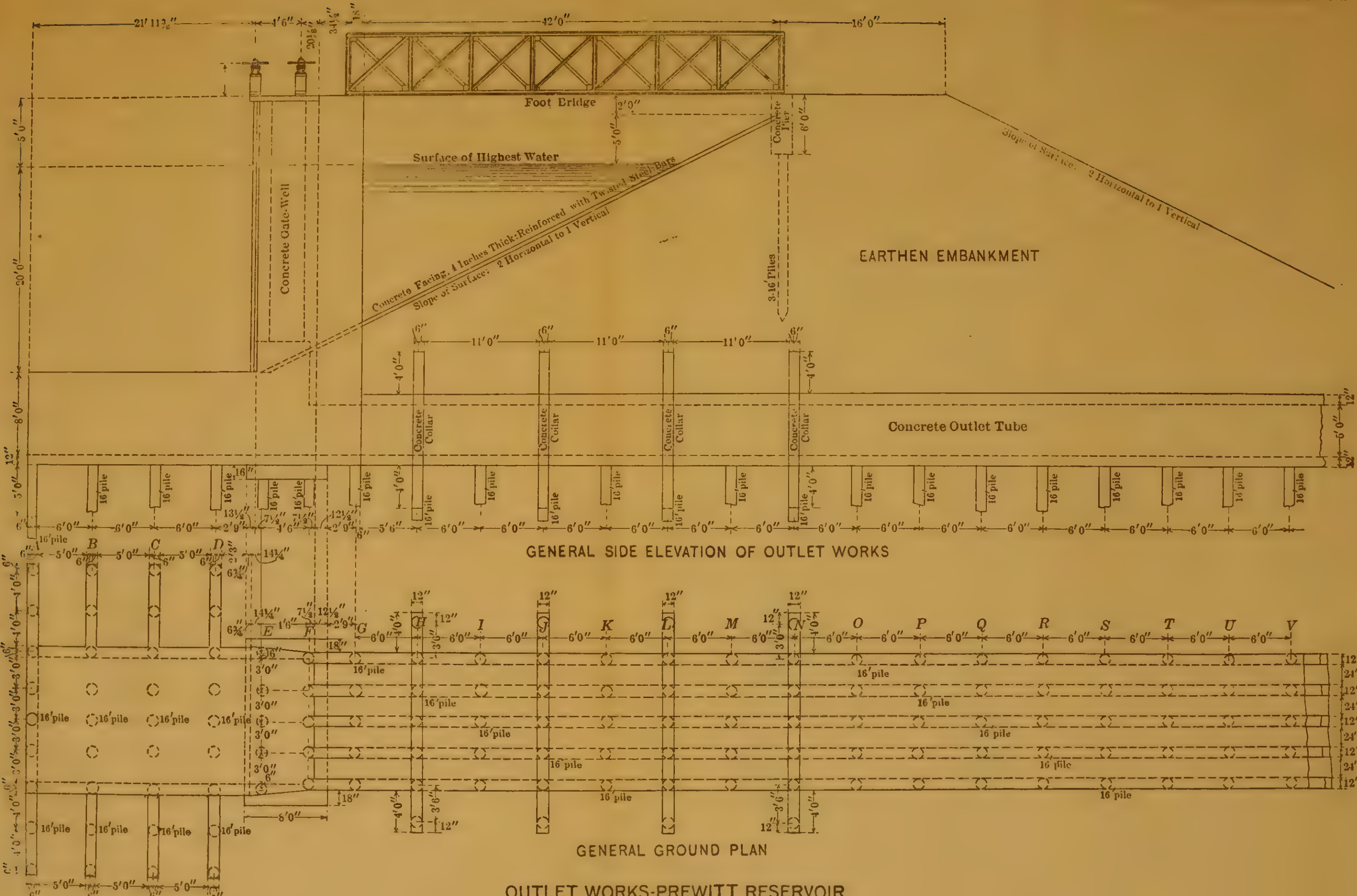
The Iliff Irrigation District.

The Iliff Irrigation District comprises an area of about 13 600 acres of cultivated land, extending along the South Platte Valley from a point about 7 miles down the river from Sterling, to a point about 32 miles below that town.

Most of this area is well improved and under cultivation. It is irrigated at present, and has been for many years, by direct diversion from the river, through the following ditches: The Iliff and Platte Valley, the Powell and Dillon, the Harmony (Ditches Nos. 1, 2, and 3), the J. B., the Bravo, and the Powell and Bland.

The Logan Irrigation District.

The Logan Irrigation District comprises, also, an area of about 13 600 acres, extending along the South Platte River from a point



OUTLET WORKS-PREWITT RESERVOIR

about 14 miles up the river from Sterling, to a point about 6 miles down stream from that town.

Like the Iliff District, this area is well improved, and has been under cultivation for many years. Its water supply is dependent on direct diversion from the river, through the following ditches: The Pawnee, the Springdale, the South Platte Extension, and the Davis Brothers.

The territory in both these districts is well improved, and has enjoyed a reasonable degree of prosperity, without the advantage of an impounded water supply. It is hoped that this prosperity will be increased materially by the more certain water supply which is expected under the operation of the proposition here under consideration.

The Prewitt Reservoir Proposition.

The Prewitt Reservoir Basin consists essentially of a shallow sandy depression on the plains bordering the South Platte River. It is about 2½ miles from the South Platte River, about the same distance from the Town of Merino, on the Julesburg Division of the Union Pacific Railroad, and 13 miles southwest from Sterling.

Its improvement has consisted of the construction of an earthen embankment, about 3½ miles long, occupying about one-third of its contour; the construction of an inlet canal, 5 miles long, from the river, and an outlet canal, 2 miles long, designed for returning the impounded waters to the river for re-diversion through the ditches previously named, and application to the lands of the districts.

The Reservoir Embankment.—The reservoir embankment has a maximum height of 36 ft. This height is reached at only one place, and extends for a distance of less than 100 ft. For the greater portion of its length, the height does not exceed 25 ft., the average being about 20 ft.

It is designed with uniform slopes of 2 horizontal to 1 vertical, on the water side. Where the height does not exceed 20 ft., the outside slopes are also uniformly 2 horizontal to 1 vertical. Where the height exceeds 20 ft., the outside slopes, from the top of the embankment to an elevation 20 ft. below the top, are, likewise, 2 horizontal to 1 vertical, and, from this elevation to the base of the fill, they are 3 horizontal to 1 vertical. The top width, throughout, is 16 ft., and the crest is 7 ft. above the level of the highest proposed water in the reservoir.

The material on which the embankment is founded, and of which it is constructed, consists essentially of very fine sand mixed with a small percentage of soil.

Prior to the construction of the embankment, a longitudinal trench was excavated along the entire site, its center line being coincident with that of the embankment. This trench was made 6 ft. deep and 6 ft. wide on the bottom, with side slopes of $1\frac{1}{2}$ horizontal to 1 vertical.

Before depositing any earth for the embankment proper, this trench was partly filled with water, in which selected material was deposited in 2-ft. layers. This operation was repeated three times in the filling of the trench. The water for this purpose was pumped from a series of sixteen wells, put down just outside of the lower toe of the embankment, at intervals of about 1 000 ft. Sufficient water was thus furnished and used, to effect, not merely the moistening, but the actual puddling, of the material deposited in the trench.

The purpose of this puddled trench was to break the continuity of any seam which there might be between the soil of the site and the material of the superimposed embankment. It was also designed to cut off and intercept the channels of any dog or gopher holes which might be in the material underlying the embankment.

After the trench had been filled, and the site had been cleared of all vegetable matter and plowed to a depth of 10 in., the construction of the embankment proper was begun.

The material was deposited in layers not exceeding 1 ft. in thickness. Each layer was then thoroughly wetted, before the deposition of the next, with water pumped from the wells. Then it was rolled with a corrugated roller weighing 125 lb. per in. of length. This operation was repeated successively until the full height of the embankment was reached. The wetting of this material prior to each rolling resulted in the actual wetting of the whole layer, not the mere moistening of the surface. The contractors claim to have kept records of their pumping operations, and these disclose the fact that the volume of water pumped into the material exceeded that of the embankment itself; in other words, the volume of water put into the embankment exceeded that of the earth.

Protection of Embankment Against Wave Action.—The water side of the embankment is protected against wave action by a covering of

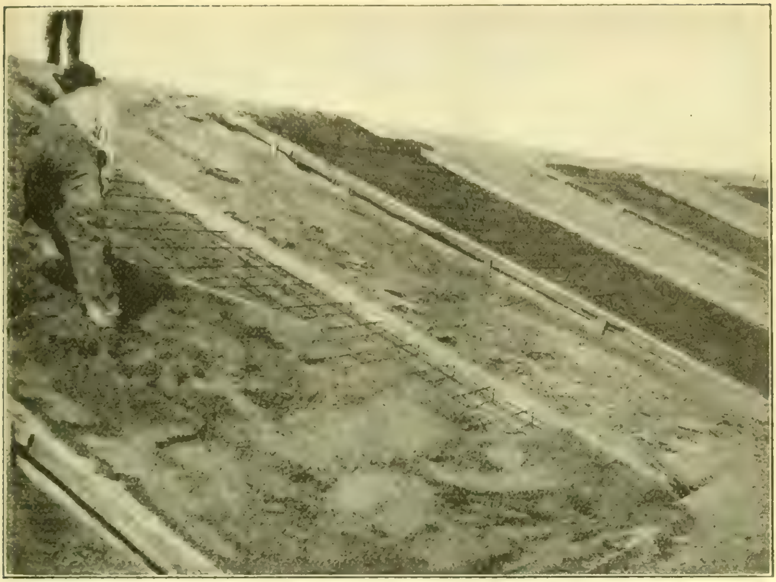


Fig. 3.—Placing Concrete Protection Slabs on Face of Reservoir Embankment.

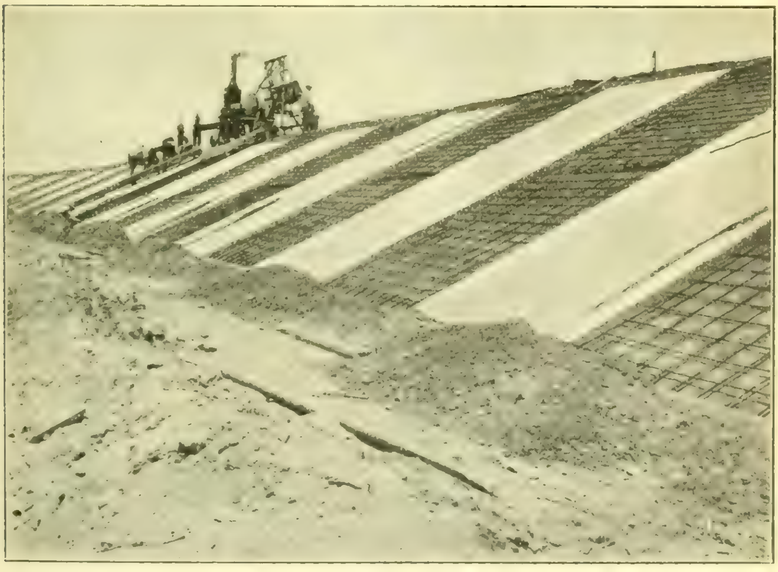
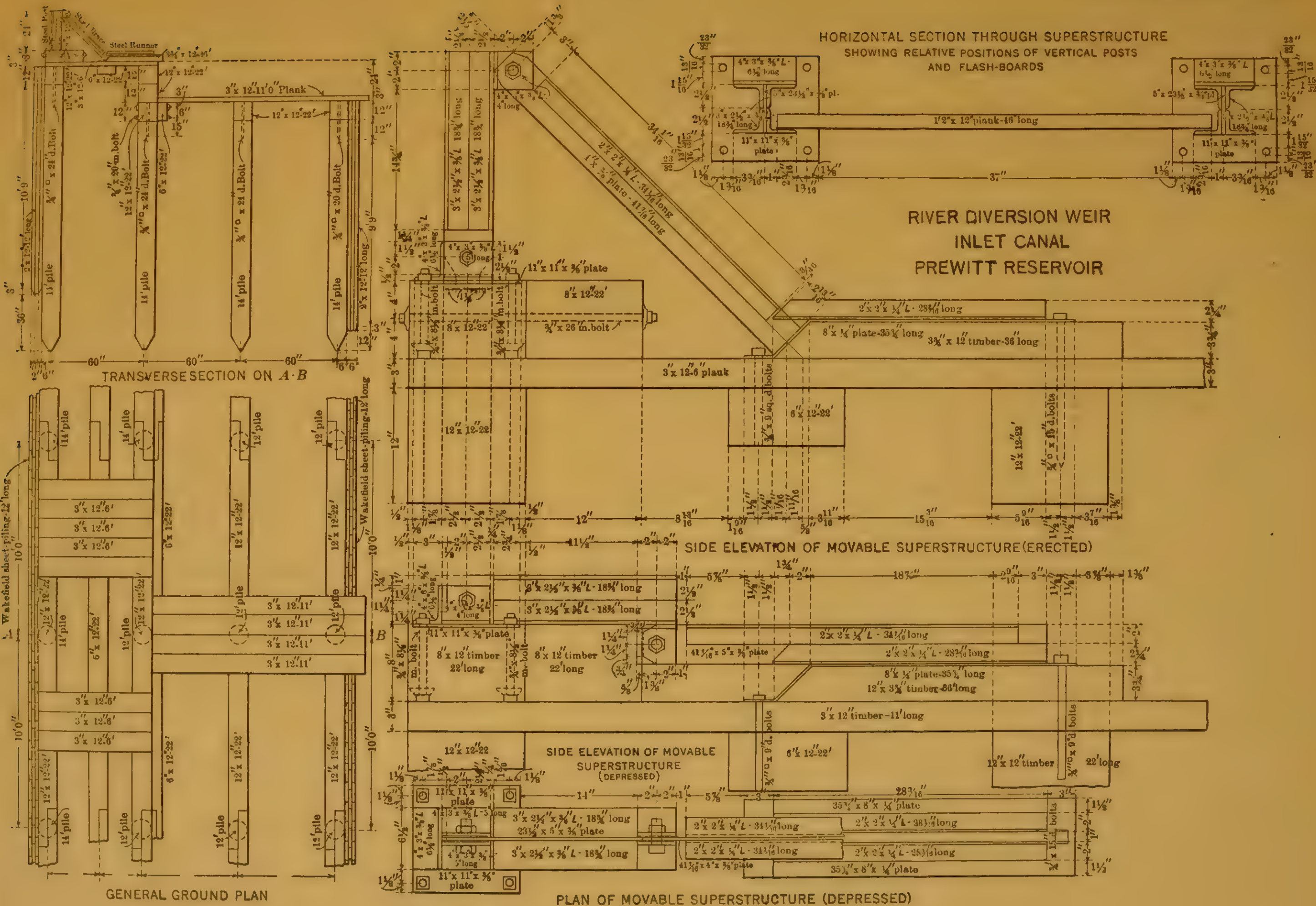


Fig. 4.—Completed Slabs, and Reinforcement Ready for Concrete for Alternate Slabs.

PLATE LXVI.
PAPERS, AM. SOC. C. E.
MAY, 1913.
ULRICH ON
PREWITT RESERVOIR PROPOSITION.



concrete, 4 in. thick, extending from its foot to within 2 ft. of its top, where it joins a vertical parapet wall of concrete. The latter is 3 ft. high, and extends 1 ft. above the crest of the embankment, and 8 ft. above the elevation of the highest proposed water in the reservoir. This parapet is 6 in. thick, and is L-shaped, with a vertical leg of 3 ft. and a horizontal leg of $2\frac{1}{2}$ ft. Both legs are reinforced in each direction with $\frac{3}{8}$-in. square, twisted bars at intervals of 12 in.

At the foot of the surface protection, and connected therewith by reinforcing rods of steel, there is a vertical "toe-wall," extending 5 ft. into the ground below the edge of the latter. This toe-wall is 6 in. thick, and is reinforced horizontally and vertically with steel bars at intervals of 12 in.

The concrete sheathing which covers the surface of the embankment is in individual slabs, each 10 ft. wide, and continuous in length from the parapet wall at the top to the toe wall at its foot.

These slabs were laid in two distinct sets, the first set being placed with intervening spaces of the same widths as the slabs themselves. After the first ones had become thoroughly set, the alternate slabs were placed. Side forms were placed for the first set of slabs, but their edges constituted the forms for the alternate set.

Under each line forming the junction of adjacent slabs, and designed for the purpose of breaking the joints between the latter, there are concrete stringers, extending from the top to the bottom of the inclined surface to be protected. These stringers are 6 in. thick and 12 in. wide, and each is reinforced with three bars of $\frac{3}{8}$-in. square, twisted, steel placed midway between the upper and lower surfaces of the stringer. The edges of adjacent protection slabs are coincident with the center line of these stringers, each slab lapping over the stringer 6 in. It was expected that this arrangement would break the joints between the edges of the slabs, and prevent the removal of sand and earth through seams which might be caused by the contraction of the slabs.

The slabs are reinforced in both directions with $\frac{3}{8}$-in. square, twisted, steel rods at intervals of 12 in. Great care was taken to ensure that these rods would be midway between the two surfaces of the concrete. The longitudinal and cross-rods were secured to one another with wire fastenings at each alternate intersection.

The concrete in all this revetment was composed of 1 part of Ideal

Portland cement and 4 parts of clean, sharp, river sand. Gravel was not used because none was obtainable within permissible transportation limits.

The Inlet Canal.—The inlet canal, conveying the water from the river to the reservoir, is 5 miles long, and is on a gradient of 0.025 per 100, equivalent to about 16 in. per mile, the computed velocity being 2.9 ft. per sec., with the canal running full.

The canal has a uniform bottom width of 20 ft., and side slopes of 2 horizontal to 1 vertical. It is built through a comparatively level country, and has an embankment on each side. The top width of these embankments is 10 ft., and the crest elevation is 9 ft. above the bottom of the canal and 2 ft. above the elevation of highest water.

The canal is located mostly on tangents, there being only six curves, of which the sharpest is 6 degrees. Its computed discharge, for a depth of 7 ft., is about 695 cu. ft. per sec.

About 1 mile below the point where the canal is diverted from the river, a waste channel extends back to the river, a distance of 1 mile. This has been designed to assist in removing sand from the canal. It has a bottom width of 24 ft., side slopes of 2 to 1, and is designed to carry water to a maximum depth of 5 ft. It has an embankment on each side with top widths of 10 ft. and crest elevations 7 ft. above the bottom of the channel.

At the origin of this waste canal there is a double structure which effects the shutting off of either or both channels, so that the entire volume of water may be conveyed through the inlet canal to the reservoir, or back to the river through the waste channel, as may be desired.

In this structure there are two sets of regulating gates, one across each channel. There are nine gates in each set, each gate serving to close an aperture 4 ft. wide. The tops of the gates in each set are at the same elevation, but the bottoms of those for the waste channel are 2 ft. lower than those for the inlet canal. The latter are at the same elevation as the grade line of the inlet canal. This arrangement was made in order to increase the gradient in the first mile of the inlet canal at times when it might be desired to sluice sand out of it. At such times, the check-gates across the inlet canal will be closed, and the waste-gates opened, which will cause an increase of 2 ft. in the effective gradient of the inlet canal from the river to this point. When

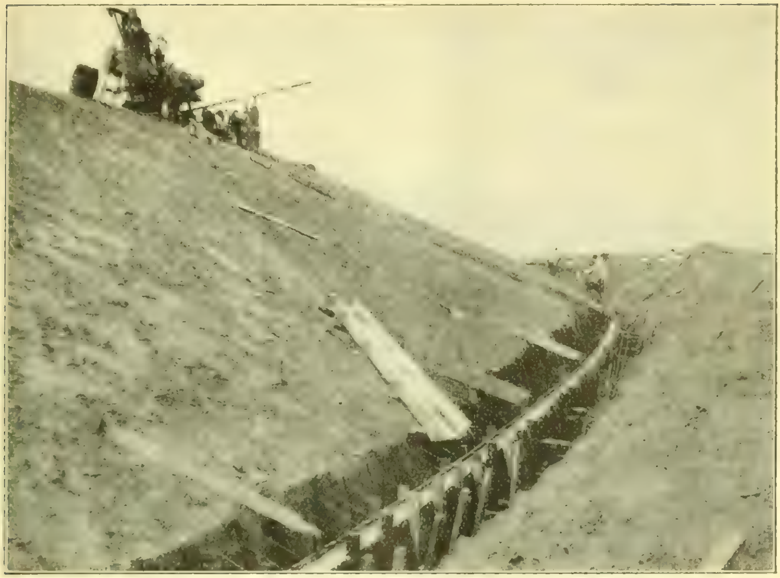


FIG. 5.—TOE-WALL IN THE FORMS.

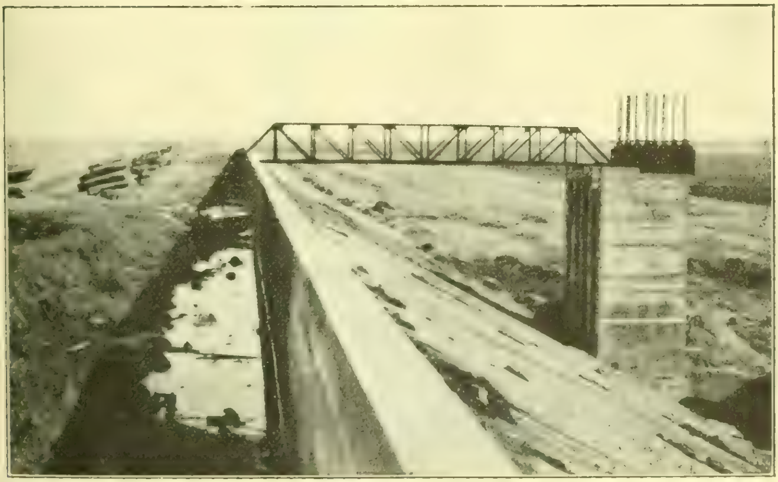


FIG. 6.—SIDE VIEW OF OUTLET WORKS FROM THE RESERVOIR, SHOWING CONCRETE PROTECTION ON FACE OF EMBANKMENT.

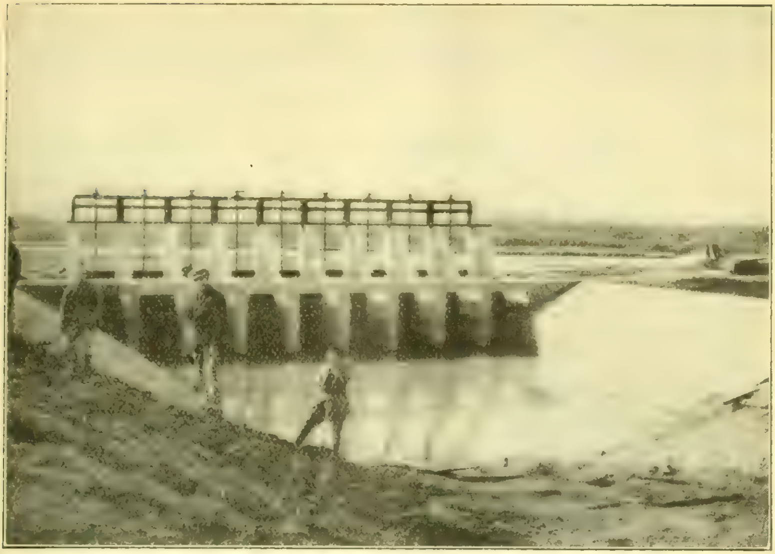


FIG. 7.—REAR VIEW OF HEAD-GATE STRUCTURE, HEAD OF INLET CANAL.

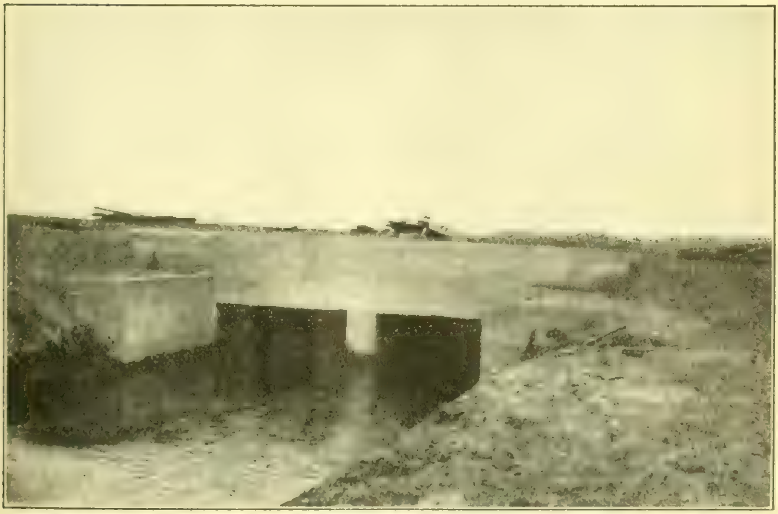


FIG. 8.—CONCRETE CULVERT OR SIPHON CONVEYING CANAL UNDER OUTLET CANAL FROM RESERVOIR.

the sluicing operations are concluded, the waste-gates will be closed and the check-gates opened, thus restoring the normal gradient in the inlet canal.

Structures on the Inlet Canal.—The head-gate at the origin of the inlet canal is of concrete, reinforced with ½-in. square, twisted, steel bars, and is founded on round piles, driven 12 ft. into the ground. It has nine 4 by 9-ft. apertures, closed by steel gates operated by rising screw stems, 2½ in. in diameter at the root of the thread. The gates are raised and lowered by hand-wheels, operating on steel balls running in bronze grooves.

The sides, partitions, and floors are 12 in. thick, and are reinforced with ½-in. square, twisted, steel bars, in horizontal and vertical pairs, at intervals of 12 in., making 4 lin. ft. of reinforcing rod to each cubic foot of concrete.

The double structure at the point where the waste canal originates is composed of two parts, each in all essential respects similar to the head-gate just described, except that the heights of the gates differ, and the waste structure has a drop of 3 ft. beginning a short distance behind the gates, thus combining the functions of a waste-gate and a drop.

There are four concrete drops on the inlet canal, designed for the purpose of accommodating it to the fall of the country in excess of that required for the gradient of the canal. Three of these lower the grade of the canal by 3 ft. each; the fourth is at the terminus of the inlet canal, where it enters the reservoir basin, and consists of two successive drops of 5 ft.

In all cases these drops consist of reverse circular curves in vertical planes, and the sides of the structures conform to the section of the canal, with slopes of 2 horizontal to 1 vertical. Each has five cut-off walls extending below the floor and sides to depths of 5 ft. or more. These walls rest on round piles, driven 12 ft. into the ground. The sides, floors, and cut-off walls are in all cases 12 in. thick, and are reinforced in the manner described for the head-gate structure, involving 4 lin. ft. of steel rod for each cubic foot of concrete.

There are nine bridges crossing the canals of this system. These are all steel spans on concrete abutments, no obstructions being permitted in the channels, aside from the partitions in the head-gate and bifurcation structures, which could not be avoided.

The Outlet Canal.—The outlet canal from the reservoir to the river is 2 miles long. Its bottom width is 22 ft., its side slopes are 2 horizontal to 1 vertical, and it is designed to convey a maximum depth of 5 ft. Its embankments are 10 ft. wide, with a crest elevation of 7 ft. above the bottom of the canal, or 2 ft. above the highest proposed water.

It has a gradient of 2 ft. per mile, thus inducing a theoretical velocity of 3.1 ft. per sec. when running at full capacity, with a discharge of about 525 cu. ft. per sec.

In addition to a concrete rating weir, a distribution gate for delivering water to the South Platte Extension Ditch, and two concrete siphons for conveying the water of certain lateral ditches from the South Platte Ditch under its channel, there are only two important structures on this line. One of these is a siphon for carrying the waters of the South Platte Ditch under this canal, which crosses the line of the latter; the other is a 5-ft. drop, similar in all respects to those already described.

The River Diversion Weir.—The river channel, at the point of diversion of the inlet canal, has a width of about 1 500 ft., from bank to bank. Only about 400 ft. of this distance, however, carries water during ordinary stages of the river. The remainder consists of low-lying lands traversed by minor channels, which are ordinarily dry, but are submerged and carry considerable volumes of water during flood periods.

The diversion weir consists of two structures of distinctly different types, which will be designated as Divisions One and Two.

Division One occupies that portion of the river bed which has been described as the channel proper, through which the normal flow is discharged. It consists of a framed timber structure founded on four rows of round piles driven 12 ft. into the sands of the river bed, and two rows of Wakefield sheet-piling designed as cut-off diaphragms for preventing the passage of water under the structure. Each piece of the Wakefield sheet-piling, consists of three pieces of 2 by 12-in. plank, 12 ft. long, fastened with 60-penny wire spikes, in the form of a tongued and grooved member.

This structure has on its top a movable device which can be elevated or depressed, as may be desired. In periods of very high water, when

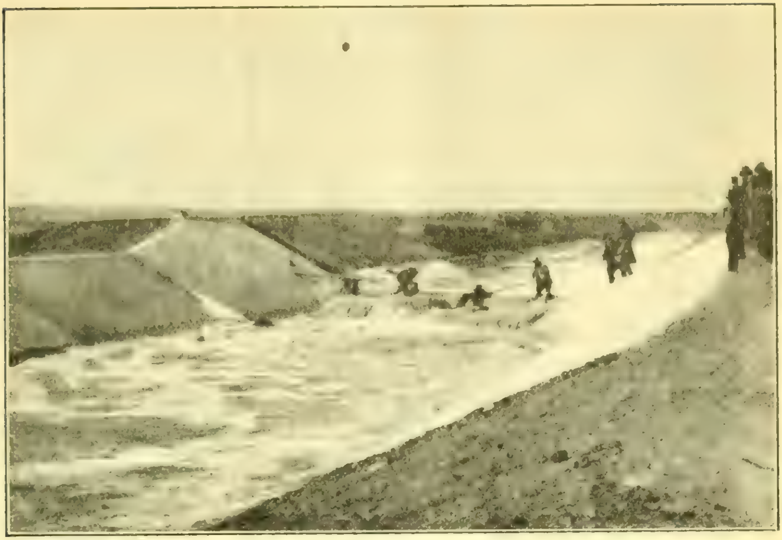


FIG. 9.—THREE-FOOT DROP IN INLET CANAL TO RESERVOIR.

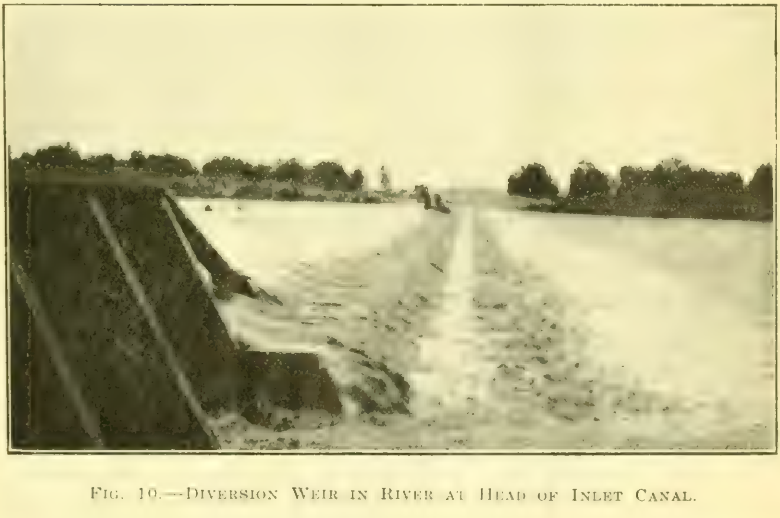


FIG. 10.—DIVERSION WEIR IN RIVER AT HEAD OF INLET CANAL.

the adjoining lands would be in danger of overflow, it is intended that this movable superstructure will be depressed, giving a larger waterway for the passage of flood-waters. At other times, when the flow is normal, it will be elevated, raising the surface to the elevation of highest water in the canal.

The crest of the fixed structure is about 2½ ft. above the natural surface of the river channel and 5 ft. above the floor of the head-gate of the inlet canal, the latter being 2½ ft. below the natural bed of the stream. The movable device permits of the elevation of the effective crest by 2 ft.

This division of the diversion weir is provided with two sluiceways, regulated with flash-boards, which when opened permit the water in front of the weir to be lowered to an elevation 2 ft. below the crest of the fixed structure. One of these is at the end of the weir next to the head-gate; the other is near the middle of the portion designated as Division One. Each is 30 ft. wide and is divided into six 5-ft. openings, separated by steel girder diaphragms designed for supporting flash-boards. The length of this division of the structure is 435 ft.

Division Two of this structure occupies, and closes permanently, that part of the channel which in ordinary stages of the river is practically without water. It consists essentially of an earthen fill, 20 ft. wide on top, with 2 to 1 side-slopes, and protected on the upstream side with concrete in the same manner as the reservoir embankment, except that, in this case, there is no vertical parapet wall at the top of the protection.

For the purpose of preventing the passage of water through the sands of the river bed under this embankment, a line of Wakefield sheet-piling 14 ft. long was driven along its center line from one end to the other. This sheeting was driven to depths varying from 10 to 12 ft., and its upper ends project above the surface, to heights varying from 2 to 4 ft., and thus extend into the embankment.

The total length of this structure is 980 ft. Its connection with Division One is effected by a concrete wall which rests on piles and is buttressed on the side in contact with the earthen structure. The elevation of the top of this structure is 7 ft. above the fixed crest of Division One, or 5 ft. above the top of the movable superstructure thereof when the latter is erected.

General Comments.

It is not claimed for this proposition that it embodies any remarkable or unique features of unusual interest or superiority. The basin itself is by no means typical, its area being out of proportion to its depth. It occupies a site which is very sandy, and it is expected that much water will be lost by percolation and seepage during the early years of its operation.

Its unusual extent of embankment (3½ miles in length), constructed almost entirely of fine sand, and founded on the same material, carries with it a definite liability which cannot be entirely ignored, even though the danger does not appear to be imminent.

In its extremely short inlet of 5 miles, and its outlet to the river of 2 miles, both constructed through a comparatively level country involving no physical problems of difficulty, it has, however, a natural advantage which is not found, to a like degree, in any similar proposition in the South Platte Valley.

The feature of merit which is claimed for this proposition, as distinguishing it from most others heretofore developed by private enterprise in this region, is the substantial and permanent character of its structures.

Aside from the diversion weir across the river at the origin of the inlet canal, there is not a structure in the work which is not executed substantially of reinforced concrete or steel.

All these structures have been built under specifications which were more than ordinarily exacting, and the work has been executed in more definite conformity to the specifications than has been customary in most developments of this character.

With reference to the probable permanence and effectiveness of the works, there appear to be no reasonable grounds for apprehension, aside from the uncertainty that must be faced as to the possibility of protecting effectually an earthen embankment of friable material against the destructive effects of wave action during the high winds which frequently prevail in the plains regions during the spring.

In the writer's opinion, absolute safety, under these circumstances, cannot be predicated of an earthen embankment constructed of material readily responsive to erosion, the protection of which depends merely on a sheathing of concrete covering a material which, in itself, has no power of resistance against the erosive action of moving water.

Though the concrete protection here under consideration has been executed more effectively than can be claimed for most works of this character with which the writer is acquainted, and though its design embodies every precaution that he was able to devise, within the limits of expense that could be borne by the enterprise, he cannot escape the conviction that definite uncertainty exists as to the entire efficiency of this and other works of like character, created with the same end in view.

The development of this proposition involved the placing of 16 700 cu. yd. of concrete, in the composition of which 121 000 sacks of cement, and 660 tons of reinforcing steel were used. In addition to the reinforcing steel, about 90 tons of structural steel were used in building the structures, exclusive of the nine steel bridges crossing the different canals. The total expenditure was somewhat less than $700 000.

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FLOOD FLOWS.

By Weston E. Fuller, M. Am. Soc. C. E.

To be Presented October 15th, 1913.*

The determination of the magnitude of the maximum flood that may be expected to occur on a river is of importance in many problems connected with engineering works. The problem is a complex one because floods are produced by combinations of a large number of conditions, many of which are themselves variable quantities.

Floods which have occurred on some rivers have been greatly in excess of others on the same river. These great floods come rarely on any one river, but an extraordinary flood occurs on some river every year. A study of their past frequency gives the best indication of what may be expected in the future.

The object of this paper is: 1st, to present a study of the frequency of floods; 2d, to show the relation between the catchment area and the magnitude of the flood; and 3d, to present formulas and tables to serve as an aid to judgment in estimating the probable maximum flood to be expected on a river.

Formulas for problems of this nature should be considered only as convenient and simple means of expressing the data. They serve as a framework on which to arrange the data in an orderly manner, so that they can be better understood and more readily used. The formulas are of value only when accompanied by clear and concise

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* This meeting will be held at New Orleans, La.

tables of data. The tables here presented contain coefficients deduced from the data for many streams. These coefficients show the flood-producing capacity of the streams. Coefficients are given for streams in various parts of the country, and should prove of service in selecting coefficients for others for which local data are not available.

The conditions which produce or affect floods may be divided into two classes: First, those which relate to one stream and tend to make all floods on it greater or less than on others; and second, those which are general in their effect, as far as area is concerned, but are variable in time, tending to produce floods of various magnitudes from time to time.

In the first class may be included the following: The prevailing conditions of rainfall; the size, shape, and slope of the catchment area; the character of the soil and vegetation on the catchment area; the physical characteristics of the stream channel; the storage capacity in reservoirs, and many other physical characteristics of the catchment area and the stream itself. Some of these characteristics may be changed in time by the action of the elements or by the works of man, otherwise, their effect on floods may be considered as constant.

In the second class may be included the following: The rate of rainfall; the snow conditions; the temperature conditions; the quantity of water stored in reservoirs, lakes, and ground at the time the flood occurs; the velocity and direction of the storm; the formation of ice dams or other temporary obstructions in the river; and the many other elements which cause one flood to differ from another on the same stream.

No two floods are exactly alike. Two storms of like intensity, velocity, and direction passing over a catchment area may produce different floods. One coming at a time when the water in the ground and in the lakes and reservoirs is low may produce only a moderate flood. A second, coming at a time when the lakes, reservoirs, and ground are filled, may produce a large flood; or, if the second occurs in conjunction with high temperature, when there is a large quantity of snow on the water-shed, a very large flood may occur.

When the great variety of conditions which affect each flood is considered, it will be seen that the number of combinations which may occur is infinite. When many conditions tending to large floods occur coincidently with great rainfall, extraordinary floods are produced.

The chances of such a coincidence may be considered equal for different streams. Clearly, the study of the effect of elements of this class is one in probabilities.

A study based solely on the larger floods would be misleading, as a flood of a size which would be ordinary on one stream may be extraordinary on another stream. It is essential, then, to study each river separately, and to establish some standard which represents a normal flood on that river before the study of the probability of the occurrence of extraordinary floods is undertaken.

The standard selected for this use in this paper is the average yearly flood. By using this average flood, the effect of the variable elements is neutralized to a large extent, so that a direct comparison of one river with another is possible. Also, a comparison of the larger floods with the average flood on the same stream gives a means of determining the frequency with which the former occur.

To give a clearer idea of the scope of the paper and of the methods used, a few definitions, a summary of the more important conclusions, and a statement of the formulas proposed are here given.

Unit of Flood Measurements.—All quantities of flood flow are stated in cubic feet per second.

Twenty-four-Hour Average Flood.—Unless otherwise stated, all floods are on the basis of the average rate of flow for 24 consecutive hours. Most of the data available are on this basis, which is the standard used in publications of the United States Geological Survey.

Maximum Rate of Flood.—As in many engineering problems it is important to know the maximum rate of flow of the flood, a separate study is made to show the relation between the maximum rate of flow and the 24-hour average rate of flow.

Yearly Average Flood.—The yearly average flood of a stream is obtained by selecting the maximum 24-hour average flood for each year and taking the average of these floods.

Frequency of Occurrence of Floods.—By frequency is meant the probable time interval, in years, between the occurrence of floods of approximately the same magnitude.

Nomenclature.—

Q = the greatest average rate of flow for 24 consecutive hours during a period of years, in cubic feet per second;

Q (Max.) = the maximum rate of discharge of a flood, in cubic feet per second;

Q (Ave.) = the average yearly flood, in cubic feet per second;

T = the number of years in the period considered;

A = the catchment area of the river, in square miles;

C = a coefficient which is constant for the river at the point of observation.

Formula Proposed, as Obtained by Plottings of the Existing Data on American Rivers.—

$Q = C A^{0.8}$ $(1 + 0.8 \log. T)$, in which Q is the largest 24-hour average rate of flow to be expected in a period of T years.

Q (Max.) $= Q\,(1 + 2\,A^{-0.3})$ in which Q (Max.) is the maximum rate of flow to be expected under the same conditions.

SUMMARY OF CONCLUSIONS.

(1) Though flood flows on different rivers vary greatly, some of the characteristics of the rivers affect the floods in substantially the same manner throughout the country; and expressions may be derived which show these effects.

(2) The effect of the size of the catchment area on the flood flows throughout the country is much the same; and this relation between the size of the catchment area and the size of the average yearly flood may be represented approximately by the expression,

$$Q \text{ (Ave.)} = C\,A^{0.8}$$

such being true only in the case of the 24-hour average rate of flow of the floods.

(3) The relation between the maximum rate of flood flow on a stream in a period of years, and the maximum rate of flow for 24 hours during the same period, may be represented approximately by the expression,

$$Q \text{ (Max.)} = Q\left(1 + \frac{2}{A^{0.3}}\right) = Q\,(1 + 2\,A^{-0.3}).$$

Table 1 gives the relative size for the maximum rate and the 24-hour average rate for different catchment areas, according to this relation.

(4) On streams throughout the country, floods which are a certain ratio of the average yearly flood occur with much the same frequency, and, on the average, the probable maximum flood in a period of years may be represented by the expression,

$$Q = Q \text{ (Ave.)}\,(1 + 0.8 \log. T).$$

TABLE 1.—Relation Between Maximum Flood and Average 24-Hour Flood.

Q (Max.) = Q $(1 + 2\,A^{-0.3})$.

Catchment area, in square miles. (1)	Ratio of maximum flood to average 24-hour flood. (2)	Catchment area, in square miles. (1)	Ratio of maximum flood to average 24-hour flood. (2)
0.1	5.0	500	1.31
1.0	3.0	1 000	1.25
5.0	2.23	5 000	1.15
10	2.0	10 000	1.12
50	1.62	50 000	1.08
100	1.5	100 000	1.06

Table 2 gives the relative size of flood which may be expected in periods of years, according to the foregoing relation.

TABLE 2.—Relation Between Flood to be Expected in a Series of Years and the Average Yearly Flood.

$Q = Q$ (Ave.) $(1 + 0.8 \log. T)$.

Time, in years. (1)	Ratio of largest flood to average yearly flood. (2)	Time, in years. (1)	Ratio of largest flood to average yearly flood. (2)
1	1.00	50	2.36
5	1.56	100	2.60
10	1.80	500	3.16
25	2.12	1 000	3.40

(5) Coefficients may be obtained for streams by utilizing the foregoing relations to discount the effect of the length of period of observation and the size of the catchment area; these coefficients will serve as a gauge for the flood-producing capacity of the streams; and the difference in value of these coefficients is caused by the various physical characteristics of the river and its catchment area, such as storage, soil conditions, etc., and by the difference in the prevailing rainfall conditions.

Data.—The data available for a study on flood flows consist of records of floods on many streams covering periods of a comparatively few years, of a few continuous records for long periods, and of many scattered data of single great floods. In recent years, the U. S. Geological Survey has obtained observations on a large number of streams, either by its own observers or in conjunction with interested parties.

The Survey has also collected many data from old records. Many State commissions or officers have collected and published data. Some of the best records are those kept by water-power or manufacturing corporations.

Records of the same floods, as quoted in different reports and books, vary frequently. It has been possible sometimes to follow these records to their original source and obtain the most probable value, but undoubtedly many inaccuracies exist. It is believed, however, that in the main the data may be considered as sufficiently reliable to form a basis for a study of this character. At all events, it is the best available at the present time. It is very fortunate that there are a few records which are both accurate and complete, and cover periods of sufficient length to make them of great value. These observations have been made by those who appreciated the value of such records, and to whom accuracy was of the first importance.

The estimates that have been made of flow during great floods on rivers where regular gaugings have not been made are of considerable value as a check on the frequency of occurrence, although many of these estimates are only rough approximations, as an adequate basis for estimate is rarely at hand, especially after the event.

There are probably in existence many other data. The writer has used all that he has at hand, the accuracy of which was not questionable.

The method of rating rivers which is used in this paper, involving as it does simply the observation of the single largest flood in each year, makes it possible to rate a large number. An approximate value for the average flood, and for the coefficient, C, may be obtained from only 5 or 6 years' continuous records.

Effect of the Size of the Catchment Area.—The effect of the size of the catchment area on flood flows is first studied for 24-hour average floods. The method used is to compare the average yearly floods for different rivers. The use of these floods, though it eliminates the effect of the variable conditions involving time, does not in any way eliminate the effect of the constant factors, such as prevailing rainfall conditions, soil conditions, slope, storage, etc. These latter factors are of such importance that floods on streams in one section of the country may be many times larger than those on streams of similar size in another section; and, even in the same section, wide variation

may occur on streams of about the same size. In order to make a comparison which will show the effect of the size of the catchment areas, the streams must be grouped in such a way that the effect of these constant factors will be similar. There are so many of these factors that no grouping can be arranged that will make all of them even approximately equal. On the whole, it seems best to subdivide the country into sections which will have similar conditions as to rainfall and climate, and to rely on the average of a large number of streams to eliminate the effect of the remaining factors. For this purpose the following subdivision by the U. S. Geological Survey may serve as well as any other:

New England States,
Hudson River Basin,
Middle Atlantic States,
South Atlantic States,
Ohio River Basin.

St. Lawrence River Basin,
Hudson Bay,
Upper Mississippi River Basin,
Missouri River Basin,
Lower Mississippi River Basin.

Western Gulf of Mexico,
Colorado River Basin,
Great Basin,
Southern Pacific Coast,
Northern Pacific Coast.

Tables 12 to 26 contain data on the average yearly floods for the rivers. The data from these tables are plotted on Plates LXVII, LXVIII, and LXIX.

The rivers in some of these divisions are so much alike in their characteristics that they have been plotted on the same diagram as follows:

Plate LXVII { New England States, Hudson River Basin, Middle Atlantic States, and South Atlantic States.
(*a*) Ohio River Basin.
(*b*) St. Lawrence River Basin and Upper Mississippi River Basin.

Plate LXVIII	Missouri River Basin and Lower Mississippi River Basin.
	Western Gulf of Mexico and Colorado River Basin.
Plate LXIX	Northern Pacific Coast and Southern Pacific Coast.

The rivers of the Great Basin and Hudson Bay vary so widely in their flood flows that no plottings have been made.

A study of these diagrams, which are on logarithmic scales, shows that, though the plottings cover zones of considerable width, the general slope of these zones is definite, and may be represented by the lines drawn. The data for the rivers on the Eastern Coast are the best, and the diagram for them shows the relation well. The slope of these lines is 0.8, so that it may be stated that the average rate of flood flow during 24 hours varies as the 0.8 power of the catchment area, or Q (Ave.) $= C\ A^{0.8}$.

The plotting for the Lower Mississippi and Missouri Rivers would indicate a slope of less than 0.8. An examination of the characteristics of the rivers on these basins, however, shows that the smaller ones are mainly mountain streams, and the larger ones flow through flat country. There is, therefore, an unbalanced element of difference in the data which may account for the apparent difference in the results.

The general indications do not justify any change in the value of the exponent for different sections; and though the data for some sections are not as satisfactory as for others, it is believed that this relation holds generally throughout the country.

All the plottings made on these diagrams are for a 24-hour average flow, and the formula, Q (Ave.) $= C\ A^{0.8}$, holds for such only. In this it differs from some other formulas proposed, and should not be compared with them.

Maximum Rate of Flood.—For all floods the maximum rate of flow will exceed the average for 24 hours. For the larger streams the rate of run-off will be of considerable magnitude for at least 24 hours, and for small streams a cloud-burst may cause a flood which will run off in a few hours, giving a large maximum rate with only a moderate 24-hour average rate. We should expect then that the maximum rate of flood, as compared with the average rate for 24 hours, will be greater for small than for large rivers.

There are not sufficient data available to admit of a satisfactory independent study of the maximum rates in comparison with the sizes

PLATE LXVII.
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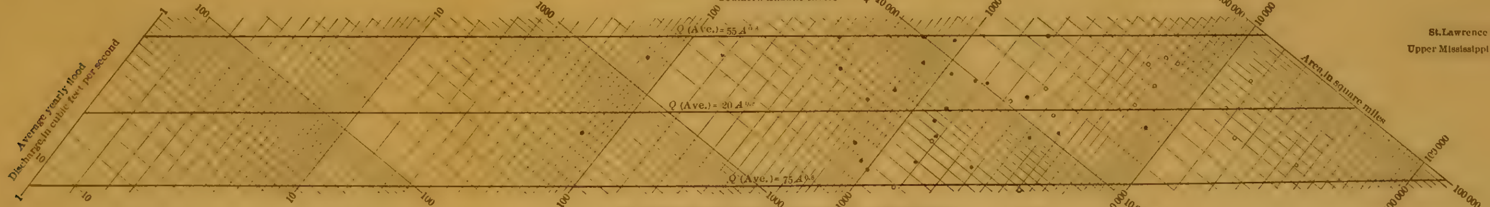
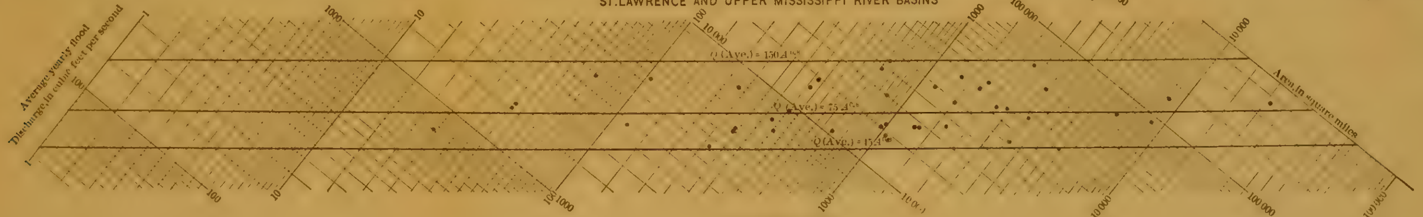
RIVERS OF THE ATLANTIC COAST

New England Rivers — ●
Hudson River Basin — ○
Middle Atlantic Rivers — △
Southern Atlantic Rivers — +



St. Lawrence River Basin — ●
Upper Mississippi River Basin — ○

ST.LAWRENCE AND UPPER MISSISSIPPI RIVER BASINS



OHIO RIVER BASIN

of the catchment areas. It seems best, therefore, to study the relation between the maximum rate of flow and the 24-hour rate of flow. We are interested more particularly in the maximum rate of the great floods. That is, we want to ascertain the probable maximum rate of flood which is likely to occur in a long period. The greatest maximum rate of flood during a period of years does not necessarily occur during the same flood that gives the maximum 24-hour flood. The larger of the 24-hour floods are usually produced by storms of considerable duration, so that the relative excess of the maximum rate over the 24-hour average rate will not be so great for the large 24-hour floods as it will be for smaller 24-hour floods. In Table 3 is shown the rivers for which both the maximum and the average 24-hour rates were obtained. In some cases these represent different floods, but generally they repre-

TABLE 3.—Relation Between Maximum Rate of Flow and 24-Hour Average Rate of Flow for Certain Floods.

Name of river.	Catchment area, in square miles.	Rate of Flood Flow, in Cubic Feet per Second.		Ratio, maximum to average.	Ratio of excess of maximum over average to the average.
		Maximum.	Average for 24 hours.		
(1)	(2)	(3)	(4)	(5)	(6)
Sylvan Glen	1.18	337	87	3.87	2.87
		66.8	39.6	1.67	0.67
Starch Factory	3.4	372	250	1.48	1.48
		337	183	1.84	
		1 123	434	2.60	
Fomer (average of 4 largest floods)	13	2 379	788	3.00 } 3.08	2.08
		2 836	672	3.30	
		2 171	628	3.45	
Tohickon	102	14 100	8 650	1.63	0.63
Neshaminy	139	19 000	9 012	2.10	1.10
Oriskany	144	4 170	3 855	1.08	0.08
Perkiomen	152	17 600	8 769	2.01	1.01
Salmon	190.5	5 670	3 800	1.47	0.47
Piscataquis	286	22 200	18 100	1.22	0.22
Passaic	823	35 000	28 000	1.25 } 1.21	0.21
		25 000	21 400	1.18	
Genesee	1 070	42 000	33 170	1.27	0.27
Penobscot	1 100	25 700	21 400	1.20	0.20
Osage	1 237	38 500	33 900	1.14	0.14
		28 500	23 250	1.22	
Mohawk (average of 3 floods)	1 306	28 500	25 250	1.13 } 1.19	0.19
		27 220	22 560	1.20	
Belle Fourche	3 250	6 270	5 941	1.05	0.05
Yadkin	3 400	130 000	104 600	1.24	0.24
Kennebec	4 270	156 000	151 000	1.04	0.04
		156 830	127 000	1.23	0.23
Merrimac	4 638	90 000	74 000	1.22	0.22
Penobscot	6 600	96 700	76 300	1.26	0.26
Savannah	7 300	309 900	276 500	1.12	0.12
Allegheny	8 700	240 900	231 600	1.04	0.04
Susquehanna	24 030	700 000	590 000	1.19	0.19
Susquehanna (ice dam)	26 766	691 000	352 900	1.90	0.90
Kansas	58 530	228 500	221 000	1.04	0.04

sent the same one. These are mainly large floods, but do not necessarily represent the maximum flood on the river. It is probable that the relation, as obtained by the average of the data in Table 3, represents one large enough for use in obtaining the probable maximum rate to be expected in a considerable term of years, although some smaller floods may have a much greater excess of maximum rate over the 24-hour average rate.

The method of obtaining the relation between the two rates of flow is shown on Table 3 and on Plate LXX. The ratio of the excess of the maximum rate of flood over the 24-hour average rate to the average rate is plotted to a logarithmic scale in relation to the catchment area, and an average curve is drawn. From this curve may be obtained the relation:

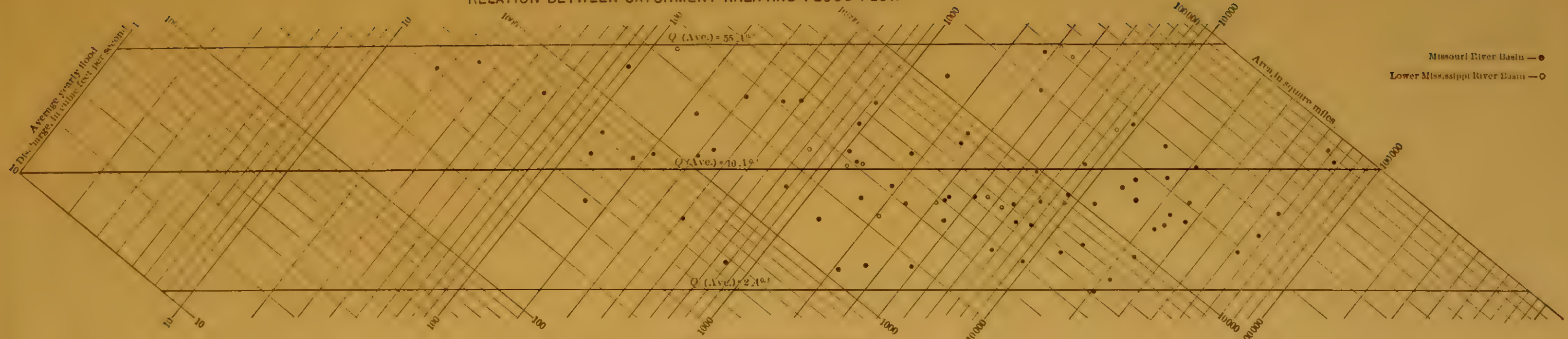
$$\frac{Q\ (\text{Max.}) - Q}{Q} = 2\ A^{-0.3} \text{ or } Q\ (\text{Max.}) = Q\ (1 + 2\ A^{-0.3}).$$

This should be considered only as an approximate average relation, from which considerable deviations in particular cases are to be expected.

The great rate of flood on the Susquehanna which is shown on the diagram was due to an ice jam, and may be considered as a rare occurrence. It should perhaps be considered as a matter of frequency of flood flows rather than as a relation between the maximum rate and the 24-hour average rate. That is, such an occurrence comes probably only in a long period of time, and during that period larger 24-hour average floods than the one given for this flood would normally occur, so that the relation between the two rates in a considerable period of years would be less than is indicated by this particular flood. Frequently, the ice dam, though it would cause a great flood immediately below the dam, would not increase to a like extent the flood some distance farther down stream, as the temporary storage along the river and in ponds and lakes will take up the water let loose by it and equalize the flow.

Frequency of Occurrence of Floods.—If the data for all the floods that have occurred in a single river for several hundred years were available, a relation could be established showing the average frequency with which floods of any size occur. As such data are not available, it becomes necessary, in order to establish the frequency relation, to utilize data for shorter periods on many rivers. Special

RELATION BETWEEN CATCHMENT AREA AND FLOOD FLOW



MISSOURI AND LOWER MISSISSIPPI RIVER BASINS

COLORADO RIVER BASIN

studies were made to see if this relation was similar for different rivers. Although considerable variation occurred for the shorter-term records, these studies showed clearly that a general law could be established. In Tables 12 to 26, the larger floods on many different rivers are compared by using the proposed formula for frequency. An inspection of these tables shows that the values of the coefficient thus obtained are, in most cases, reasonably constant, and are similar to the values obtained by comparison with the average yearly flood, thus indicating that the frequency relation holds for the different rivers.

As rivers follow the same general law, it is allowable to use the data on all the rivers in the same way as those on a single river, provided such data can be put on a common basis. The use of the yearly average flood affords a means of doing this. If the same law holds, the ratio of the larger floods to the yearly average floods should be the same for all rivers for the same period of time. The method of comparing the data and obtaining the frequency is explained in detail later.

As most of the data were obtained during the last 10 or 20 years, objections to this method of analysis may be raised on the score that weather conditions may have been different during other periods in the past, or may be different in the future. Certainly, if weather conditions throughout the country were subject to permanent changes, this objection would be well taken. There is no evidence, however, that this is so. The rivers considered are distributed throughout the United States, so that local conditions should not affect the results. We know that a dry season in one section of the country may occur during the same year as a wet season in another section. We also know that storms which cause great floods on small streams may cause only moderate floods on larger streams, and *vice versa*. Considering these facts, the diversity of the conditions, and the large area over which the rivers are distributed, it seems that periods of 10 years or more give a fair average of the conditions which have existed in the past and will probably exist in the future.

As a check on this frequency relation we have long-term records for a few rivers, which show that the relation holds approximately for these rivers. A few of these records cover a century. A further check is given by the lower diagram on Plate LXIX, on which the greatest floods of the century are plotted, showing a close relation to the proposed formula.

Method of Determining the Frequency.—As there is some choice as to the flood to be selected in the study for frequency, some matters involving the general method which has been followed are here given.

If we are given a record of floods for a series of years, we may divide it into a number of equal periods of time. Taken independently, the maximum flood in each period might be said to represent the probable flood to be obtained in that period. These maximum floods, however, will vary, and we may select the most probable maximum flood which will occur in a given period by any of the following methods.

First, the average of these maximum floods, which may be called the average maximum flood to be expected in this period of time; second, the one of these maximum floods for which there is one greater for each one less, which may be called the median maximum flood to be expected in the period of time; third, the smallest of these maximum floods, which may be considered as the flood that should be equalled or exceeded in the period of time.

As the yearly floods considered range from a fraction of the average to several times this average, it may be readily seen that there will probably be more floods of less than, than there will be of more than, the average. The average of the maximum floods, then, will exceed the median flood. It is a question which of these two floods better represents the requirements. The average flood is more easily obtained and is more accurate, particularly for short-term records. It is larger, thus leading to safe design. As the study is based on the average yearly floods, it seems better to continue the method and use the average maximum flood. The relation between the foregoing different floods seems to be constant, as is shown in the detailed method given later. It may be stated that it would have been possible to have used the median flood from the start, to have selected the median yearly flood, and to have made the study on that basis. It is believed, however, that, on the whole, the average flood method is the better.

It should be noted that the results are also affected by two other matters. First, only the single largest flood in each year is used. This eliminates all the others during that year, although they may have been greater than the largest flood in other years. If these second and third floods in some years were included in the study, they would tend to give somewhat higher values for the probable flood. On the

PLATE LXIX.
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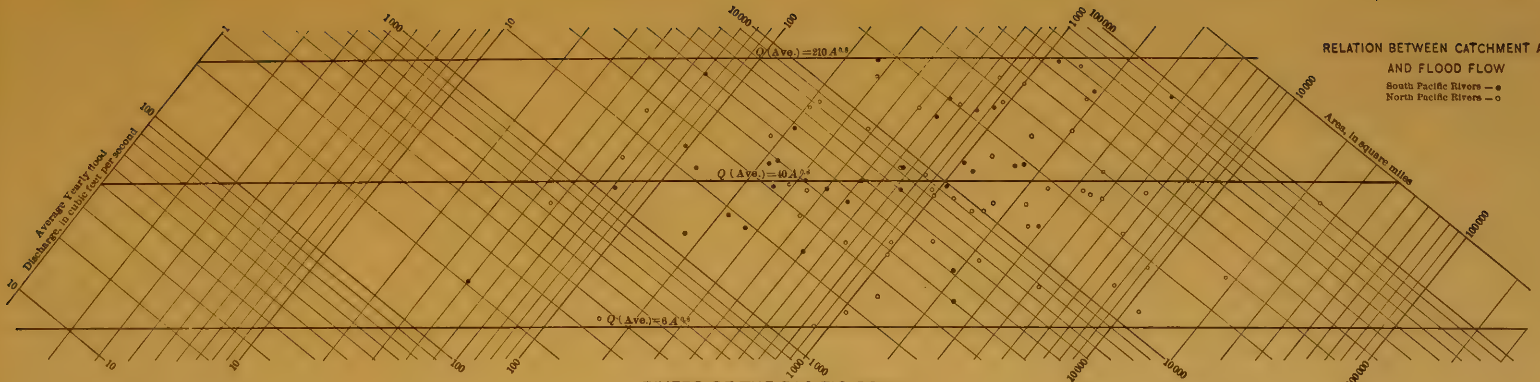
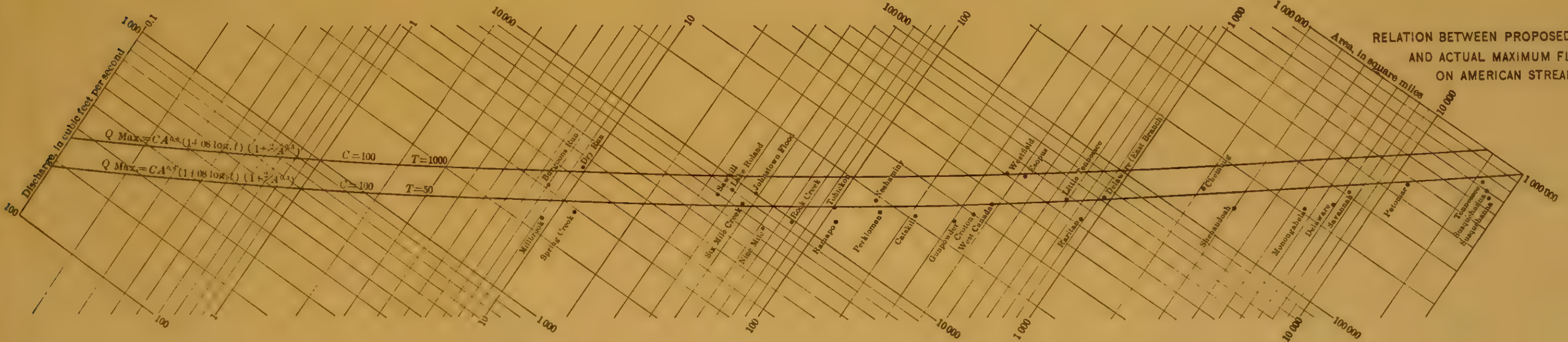
RELATION BETWEEN CATCHMENT AREA
AND FLOOD FLOW

South Pacific Rivers — •
North Pacific Rivers — o



RIVERS OF THE PACIFIC COAST

RELATION BETWEEN PROPOSED FORMULA
AND ACTUAL MAXIMUM FLOODS
ON AMERICAN STREAMS



other hand, in the method of analysis no attention is paid to the fact that some of the largest floods may come close together. It is assumed that the floods are uniformly distributed over the period, though, in fact, some periods would have two or more floods of the size under consideration while others would not contain any such flood. If this were taken into account, it would tend to reduce somewhat the value of the probable flood to be expected. These errors in methods, if they may be so called, are not of great moment. Generally, it may be said that the flood obtained by the proposed formula is probably somewhat in excess of that which we would expect to get in any one period, but it is the average of the floods in a number of periods of the same length.

General Method.—The general methods of treating the data can be best shown by a specific example. For this purpose, the writer has used Tohickon Creek, the data for which are contained in the reports of the Philadelphia Water Board for 25 years. All the steps leading up to the determination of the average flood and the frequency of occurrence of floods on this stream are shown. In working out the general formula for frequency for all rivers, the same method is followed as here given, the data for all the rivers being collected and used as if they were for one stream. This example then illustrates the entire method of procedure. The first step is to select from the daily records the largest single flood for each year. These are shown in Column 2 of Table 4. The second step is to average all these floods, as is shown at the foot of Column 2. The third step is to select and arrange the floods in order of their magnitude. This is indicated in Table 4, Q_1 representing the largest flood; Q_2 the second; Q_3 the third, etc. The next step is to find the ratio of these larger floods to the average flood. This is shown in Column 3. The next step is to arrange the data so that the frequency may be determined. The methods for doing this are shown in Table 5.

The methods of determining all the three different values for the probable flood to be expected, as previously stated, are here given.

Method of Obtaining Average Maximum Flood to be Expected.—The method of computing the average maximum flood to be expected is shown in Table 5, Part *a*. Column 1 gives the serial number of each flood, in order of size. Column 2 gives the ratio of the flood to the average flood, as taken from Table 4. Column 3 gives the summation

of all the floods equal to or exceeding the flood concerned. Column 4 gives the summation in Column 3 divided by the serial number. Column 5 gives the total number of years in the record divided by the serial number. It is evident, then, that Column 4 represents the average of the floods which occur in the period of years given in Column 5. On the first diagram of Fig. 1 the values in Columns 4 and 5 are plotted on a logarithmic scale for the values of the time (Column 5) and on an ordinary scale for the values of the ratios (Column 4); these plottings are marked A on the first diagram of Fig. 1.

TABLE 4.—METHOD OF TREATING THE RECORDS TO OBTAIN THE AVERAGE YEARLY FLOOD Q AVERAGE, AND TO OBTAIN THE RATIO OF MAXIMUM FLOODS.

River, Tohickon; Station, Pt. Pleasant, Pa.; Catchment Area, 102 sq. miles. $A^{0.8} = 58.5$.

Date. (1)	Maximum 24-hour average flood for the year. (2)	Ratio of flood to average yearly flood. (3)
1884	4 379 Q_8	1.06
1885	3 664	....
1886	5 359 Q_4	1.30
1887	2 544	....
1888	3 493	....
1889	4 714 Q_6	1.15
1890	2 942	....
1891	2 858	....
1892	3 158	....
1893	2 994	....
1894	8 650 Q_1	2.10
1895	3 857	....
1896	6 515 Q_2	1.59
1897	3 683	....
1898	4 160 Q_{10}	1.01
1899	3 222	....
1900	No record.	....
1901	4 089 Q_{12}	0.99
1902	5 958 Q_3	1.45
1903	4 968 Q_5	1.21
1904	4 395 Q_7	1.06
1905	4 175 Q_9	1.01
1906	3 200	....
1907	4 120 Q_{11}	1.00
1908	2 770	....
1909	3 050	....

Average yearly flood Q (Ave.) 102 917 ÷ 25 = 4 117.

Median Flood.—The method of obtaining the median maximum flood is shown in Table 5, Part b. The second largest flood is here taken as representing the size of that one which will probably come in one-third of the total period. That is, there will be one flood greater, one less, and one equal to it in the three periods. In the


DIAGRAM SHOWING THE EXCESS
OF THE MAXIMUM RATE OF FLOOD OVER
THE AVERAGE 24-HOUR RATE FOR
DIFFERENT CATCHMENT AREAS
Catchment area, in square miles
Ratio of excess
Rate of excess = 0.3
Sylvan Glen
Fomer
Neshaminy
Perkiomen
Tohickon
Salmon
Genesee
Starch Factory
Piscataquis
Penobscot
Mohawk (ave.)
Passaic (ave.)
Osage
Yadkin
Kennebec
Merrimac
Susquehanna
(Ice Dam)
Savannah
Kansas
Belle Fourche
Allegheny
Oriskany

same way, the third flood is taken as the most probable one for a period equal to one-fifth of the total time, and so on. Column 1 gives the serial number from Table 4. Column 2 gives the corresponding ratio; Column 3 gives the time for which this flood is the median, and is obtained by dividing the total time by one less than twice the serial number. Columns 2 and 3 are then plotted as for the first method. These plottings are marked *B* on the first diagram of Fig. 1.

TABLE 5.—TOHICKON CREEK.

PART *a*.—METHOD OF OBTAINING PROBABLE AVERAGE MAXIMUM FLOOD TO BE EXPECTED.

No. of flood, in order of magnitude. (1)	Ratio of flood to average yearly flood. (2)	Summation of ratios. (3)	Summation of ratios÷No. of floods. (4)	Time, in years. (5)
1...........	2.10	2.10	2.10	25.00
2...........	1.59	3.69	1.85	12.50
3...........	1.45	5.14	1.71	8.33
4...........	1.30	6.44	1.61	6.25
5...........	1.21	7.65	1.53	5.00
6...........	1.15	8.80	1.47	4.17
7...........	1.06	9.86	1.41	3.57
8...........	1.06	10.92	1.36	3.33
9...........	1.01	11.93	1.33	2.79
10...........	1.01	12.94	1.29	2.50
11...........	1.00	13.95	1.27	2.27

PART *b*.—METHOD OF OBTAINING MEDIAN MAXIMUM FLOOD.

No. of flood. (1)	Ratio. (2)	Time, in years. (3)
2................	1.59	8.33
3................	1.45	5.00
4................	1.30	3.57
5................	1.21	2.79
6................	1.15	2.27

PART *c*.—METHOD OF OBTAINING PROBABLE FLOOD THAT WILL BE EQUALLED OR EXCEEDED DURING A PERIOD.

No. of flood. (1)	Ratio. (2)	Time, in years. (3)
2................	1.59	12.50
3................	1.45	8.33
4................	1.30	6.25
5................	1.21	5.00
6................	1.15	4 17
7................	1.06	3.57
8................	1.06	3.33
9................	1.01	2.79
10................	1.01	2.50
11................	1.00	2.27

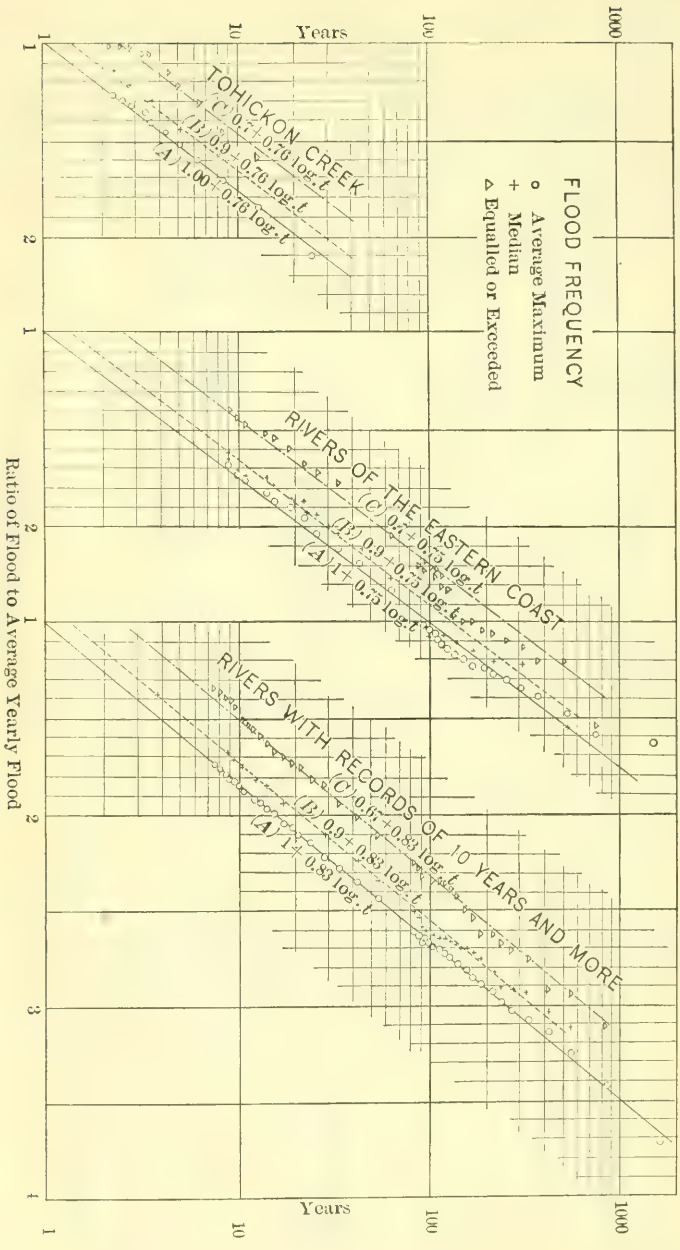

FLOOD FREQUENCY
o Average Maximum
+ Median
△ Equalled or Exceeded
TOHICKON CREEK
(C) 0.7+0.76 log. t
(B) 0.9+0.76 log. t
(A) 1.00+0.76 log. t
RIVERS OF THE EASTERN COAST
(C) 0.7+0.75 log. t
(B) 0.9+0.75 log. t
(A) 1+0.75 log. t
RIVERS WITH RECORDS OF 10 YEARS AND MORE
(C) 0.67+0.83 log. t
(B) 0.9+0.83 log. t
(A) 1+0.83 log. t
Years
Ratio of Flood to Average Yearly Flood

FIG. 1.

Flood to be Equalled or Exceeded.—The method of obtaining the flood to be equalled or exceeded is shown in Table 5, Part *c*. To obtain it we select the least of the maximum floods in the periods. The second flood is taken for one-half of the time, the third for one-third of the time, and the fourth for one-fourth of the time, etc. This means that, considering four periods, there will be three of these which will have a flood larger and one which will have a flood equal to the value which we have selected. The ratios and corresponding periods of time are marked C on the first diagram of Fig. 1.

Method of Obtaining Average Relation for Frequency for All Streams.—The method used to obtain the frequency relation for all streams investigated is the same as that illustrated for Tohickon Creek. All the data are used precisely as if they constituted a record for a single river covering a period of time equal to the sum of the length of the records for the individual rivers. In studying the matter of frequency, plottings were made for rivers in many different sections of the country. In this paper only two of these are given; first, that for all the rivers on the Eastern Coast, which represents the best data, covering the greatest length of time; second, the data for all the rivers in the United States for which records of 10 years or more are at hand. The data for the Eastern Coast rivers are given in Table 7 and are plotted on the second diagram of Fig. 1. The frequency relation for these rivers is $Q = Q$ (Ave.) $(1 + 0.75 \log. T)$. The data for all the rivers in the United States with record equal to or exceeding 10 years is given in Table 8 and are plotted on the third diagram of Fig. 1. The relation for these rivers is $Q = Q$ (Ave.) $(1 + 0.83 \log. T)$. For other sections, somewhat different relations were obtained. The difference in these relations is not great. The variation hardly justifies establishing separate values for each section, and a single one is all that is warranted. The expression, $Q = Q$ (Ave.) $(1 + 0.8 \log. T)$ is adopted as the value of the coefficient of log. T as it is between the relation established for the eastern rivers and that for all the rivers.

The relation between the average maximum, the median maximum, and the flood to be equalled or exceeded is shown in Table 6.

In studying the data, a few rivers, located principally in arid and semi-arid regions, were eliminated on account of unusual conditions. In such sections conditions are such that no floods worthy of the name

TABLE 6.—Relation Between the Average Maximum, the Median Maximum, and the Flood to be Equalled or Exceeded.

No. of years in the period.	Ratio to Average Yearly Flood.		
	Average maximum flood $Q = Q$ (Ave.) (1 + 0.8 log. T).	Median maximum flood Q (median) = Q (Ave.) (0.9 + 0.8 log. T).	Flood to be equalled or exceeded Q (equalled or exceeded) = Q (Ave.) (0.7 + 0.8 log. T).
(1)	(2)	(3)	(4)
1..........	1.0	0.9	0.7
5..........	1.56	1.46	1.26
10..........	1.80	1.70	1.50
50..........	2.36	2.26	2.06
100..........	2.60	2.50	2.30
1 000..........	3.40	3.30	3.10

TABLE 7.—Floods on Rivers of the Eastern Coast, for Which Records Were Available.

Serial number.	Ratio of flood.	Summation of Column 2.	Column 3 divided by Column 1; average of flood in this period.	Median flood which is exceeded in one-half the periods.	No. of years in the period.
(1)	(2)	(3)	(4)	(5)	(6)
1	312	312	312	...	1 532
2	305	617	308	...	766
3	271	888	296	305	511
4	271	1 159	289	...	384
5	264	1 423	285	271	306
6	260	1 683	280	...	255
7	257	1 940	277	271	219
8	255	2 195	274	...	192
9	250	2 445	272	264	170
10	250	2 695	270	...	153
11	248	2 943	267	260	139
12	234	3 177	264	...	128
13	231	3 408	262	257	118
14	226	3 634	259	...	110
* 13	225	3 378	260	257	116
14	221	3 599	257	...	108
15	221	3 820	254	255	100
16	221 210	4 041	252	...	94
21	205	4 930	234	228	64
22– 31	186	6 846	220	210	44
32– 38	177	8 066	212	205	34
39– 49	172	9 981	203	193	27
50– 54	167	10 564	196	188	23
55– 63	160	12 021	191	186	19
64– 68	154	12 689	187	185	16
69– 78	151	14 214	182	176	14
79– 89	156	15 680	176	174	11
90–100	144	17 281	173	171	10
101–114	141	19 278	168	163	9

* Two large floods eliminated, as the record was not continuous. For such cases, where the record includes a few large floods, these are used, after which the computations are adjusted by eliminating the effect of these floods and proceeding as if they had not existed.

occur in some years, though occasionally there is a large one. For such cases the average yearly flood becomes low and the percentage of the maximum flood becomes unduly high. These conditions are quite different from those generally found, and it seems best to exclude such cases. It follows, of course, that the frequency relation here proposed does not hold for such rivers.

TABLE 8.—FLOODS ON ALL RIVERS FOR WHICH RECORDS OF TEN YEARS OR MORE WERE AVAILABLE.

Serial number.	Ratio of flood.	Summation of Column 2.	Column 3 divided by Column 1; average of flood in this period.	Median flood which is exceeded in one-half the periods.	Number of years in the period.
(1)	(2)	(3)	(4)	(5)	(6)
1.....	373	...	373	...	1 672
2.....	312	685	342	...	836
3.....	293	978	326	312	557
4.....	291	1 269	315	...	418
5.....	276	1 545	309	293	337
6.....	270	1 815	302	...	278
7.....	267	2 082	297	291	239
8.....	264	2 346	293	...	209
9.....	262	2 608	289	276	186
10.....	253	2 861	286	...	167
11.....	250	3 111	282	270	152
12.....	242	3 353	279	...	139
13.....	238	3 591	276	267	129
14.....	236	3 827	273	...	120
15.....	235	4 062	270	264	111
16.....	234	4 296	268	...	104
17.....	231	4 527	266	262	99
18.....	231	4 758	264	...	93
19.....	226	4 084	262	253	88
20.....	224	5 208	260	...	84
20- 30.....	210	7 352	244	235	56
30- 40.....	200	9 410	235	224	42
40- 50.....	193	11 376	227	...	34
50- 60.....	185	13 250	221	210	28
60- 70.....	181	15 073	215	...	24
70- 80.....	175	16 844	210	200	21
80- 90.....	172	18 578	206	...	19
90-100.....	169	20 286	203	193	17
100-110.....	167	21 961	199	...	15
110-120.....	162	23 603	196	185	14
120-130.....	158	25 197	193	...	13
130-140.....	156	26 768	191	181	12
140-150.....	153	28 310	189	...	11
150-160.....	150	29 825	187	175	10.5
160-170.....	148	31 318	185	...	10
170-180.....	144	32 769	182	172	9.5
180-190.....	141	34 190	180	...	9.0
190-200.....	139	35 587	178	169	8.5
200-210.....	136	36 461	176	...	8.0
210-220.....	134	38 319	174	167	7.5
....	...	......	...	134	3.75

Table 9 contains data on a few of the largest relative floods in the United States, as compared with the average yearly floods.

TABLE 9.—Some of the Larger Floods, as Compared with the Yearly Average Floods.

No.	River.	Drainage area, in square miles.	Point of observation.	Floods, in Cubic Feet per Second. Maximum.	Average.	Ratio of maximum to average.
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1....	Kansas........	58 550 59 841	Compton Lawrence } Kans....	221 000	59 000	3.73
2....	Shenandoah...	3 000	Millvale, W. Va.......	139 700	44 800	3.12
3....	South Platte...	633	Denver, Colo..........	5 570	1 900	2.93
4....	Truckee........	955	State Line, Cal........	15 300	5 260	2.91
5....	Tuolumne......	1 500	La Grange, Cal........	52 000	18 900	2.76
6....	Savannah......	7 300	Augusta, Ga..........	310 000	114 300	2.70
7....	Schuylkill.....	1 920	Philadelphia, Pa......	82 156	30 700	2.67
8....	Passaic........	823	Dundee, N. J..........	27 995	10 600	2.64
9....	Umatilla.......	353	Gibbon, Ore...........	10 000	3 808	2.62
10.. .	Kennebec......	4 270	Waterville, Me........	151 000	59 600	2.53

Use of the Formula.

$$Q = C\,A^{0.8}\,(1 + 0.8 \log. T).$$

$$Q\ (\text{Max.}) = Q\,(1 + 2\,A^{-0.3}).$$

Selecting the Value for the Coefficient, C.—Tables 12 to 26 contain values for the coefficient, C, for many rivers in the United States. These coefficients are applicable for the river at the station where the floods were observed and for other points on the river where conditions are not materially different. Obviously, the coefficient for a river above large branches or above points where there may be considerable storage may be different from that of the river below. Slopes and other conditions affect the coefficient, and for the river at other points than where the gaugings were made, judgment must be used in its selection. The coefficient for the upper portion of a river may be different from that for the lower portion. The coefficient for the river, however, taken in connection with others for similar rivers, should enable one to select an approximate value for any river in the tables. For streams for which no coefficients are given in the tables, approximate values may be obtained by comparison with rivers having similar characteristics, for which the coefficients are given.

It may be possible to obtain local data as to the height of the ordinary yearly flood, which may give an indication of the value of the coefficient. It may also be possible to obtain records of one or two of the larger floods on the stream, and if one can ascertain the time

when these occurred, the data may be reduced by the formula of frequency to obtain approximate values of C.

Some data of this latter character are contained in Table 28. No attempt has been made to reduce these data to find the value of C, as the information in regard to the period represented is not definite. Local investigation of the conditions might enable one to form a reasonable estimate as to the period of time these floods represent. It is probable that records of other floods on these streams would be available, together with the time of the occurrence, so that approximate values for the coefficients could be established.

The effect on flood flow of such factors as slope of drainage basin, shape of drainage basin, rate of rainfall, etc., have been studied and discussed in a number of papers. For the sake of convenience, and to aid in the selection of the coefficient, C, from the tables, it may be well to summarize briefly the effect of some of these factors, stating generally their effect on the magnitude of the flood.

Storage.—Storage may be in a reservoir, or in the ground. Generally speaking, all storage tends to reduce the size of floods. Rivers on which there are many lakes or reservoirs, or on which there are large sandy areas, generally have low flood flows, as compared with rivers otherwise similar. When the lakes and reservoirs are full, the storage below the overflow is not available for reducing floods. Storage above the overflow, however, is always available, and the quantity stored, as the water rises above the overflow, is certain to reduce to some extent the flood flows in the stream below. In the same way, storage in the ground is more or less available, depending on the condition of the ground-water at that time. The effect of storage above the overflow is to reduce all floods, and the effect of storage in the ground and that below the overflow is rather to make large floods of less frequent occurrence.

The temporary storage above the overflow is the most important for natural reservoirs, such as lakes and ponds. Where reservoirs are controlled and used for power purposes, or for water supply, the storage below the overflow may be important; but as these reservoirs may be filled when the larger floods come, dependence cannot be placed on such storage.

It is evident that this storage will affect the floods resulting from different types of storms in different ways. A storm producing a

long-continued flood will fill the available storage while the supply is still at a high rate, so that the maximum rate for the flood may be nearly as great as would have occurred without the existence of the reservoir. On the other hand, a flood from a short, sharp storm will be greatly reduced by storage, because, before the storage is filled, the supply will be much less.

In order to ascertain what effect this storage may have on the maximum rate of flood, a few specific cases were considered.

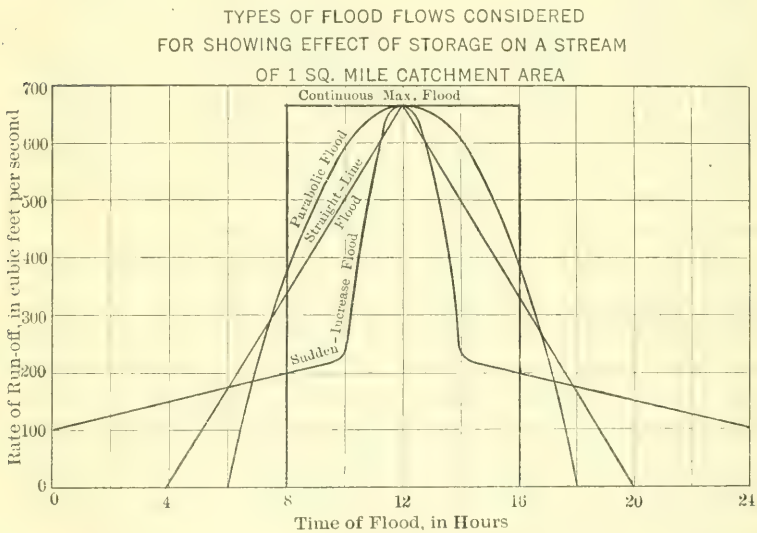


Fig. 2.

The method of computation and the results are shown on Tables 10 and 11, and in Figs. 2 to 6. The 24-hour average rate and the maximum rate are taken as given by the formulas proposed in this paper, using $C = 70$ and $T = 1\,000$, which represents an extraordinary flood on an average eastern river.

Four different types of flood flows are considered, as shown on Fig. 2. These cover in a general way the more common floods. The ideal type, called the Continuous Maximum, gives the minimum limit for the effect of storage. In these computations it is assumed that the reservoir sides are vertical and that the overflow is from a weir with vertical sides, from which the rate of overflow varies as the $\frac{3}{2}$ power of the height of the water passing over the weir.

Figs. 3, 4, and 5 show the effect of different amounts of storage for the assumed conditions. Table 10 contains a summary of the results of the computations for different cases.

Fig. 6 shows a plotting of the data in Table 10.

From these tables and diagrams the effect of this storage for the assumed conditions is apparent. The study is made for the effect on comparatively small catchment areas for which the flood at a high rate would usually not last more than 24 hours. For larger rivers, for which long-continued storms are common, the study does not apply.

The data, though based on assumptions, give an approximate idea of what the effect of such storage may be. In comparing different rivers for the purpose of selecting the value of C, the effect of lakes and reservoirs may be approximated by these data. Table 11 is a summary of the data.

The amount of storage available is dependent on the width of the overflow. Careful consideration should be given to flood reduction in determining the width of spillways of dams and the outlets of lakes. In many cases a reduction in the width of overflow may be advantageous, and, in cases where the added cost is not great, would be worth while.

Slopes.—Steep slopes on a water-shed produce rapid run-off and, generally, relatively large flood flows.

Shape of Catchment Basin.—The more nearly equal the catchment basin is divided among the branches of the river, the more chance there is of concentration of flood-water at a single point and the greater the flood flows. A compact area will produce a larger flood than a long narrow one.

Branches.—A large number of branches, affording good drainage to the catchment area, will bring the water off more rapidly than a few branches, and will cause larger flood flows.

Condition of River-Bed.—The condition of the river-bed itself is an important factor. A river-bed which has frequent points of congestion which tend to hold back the water and provide temporary storage will have smaller relative flood flows than one with a smooth even bed which allows the water to run off rapidly. The hydraulic properties of the river channel, such as the hydraulic radius and the coefficient of roughness, effect the rapidity of the run-off, and thus

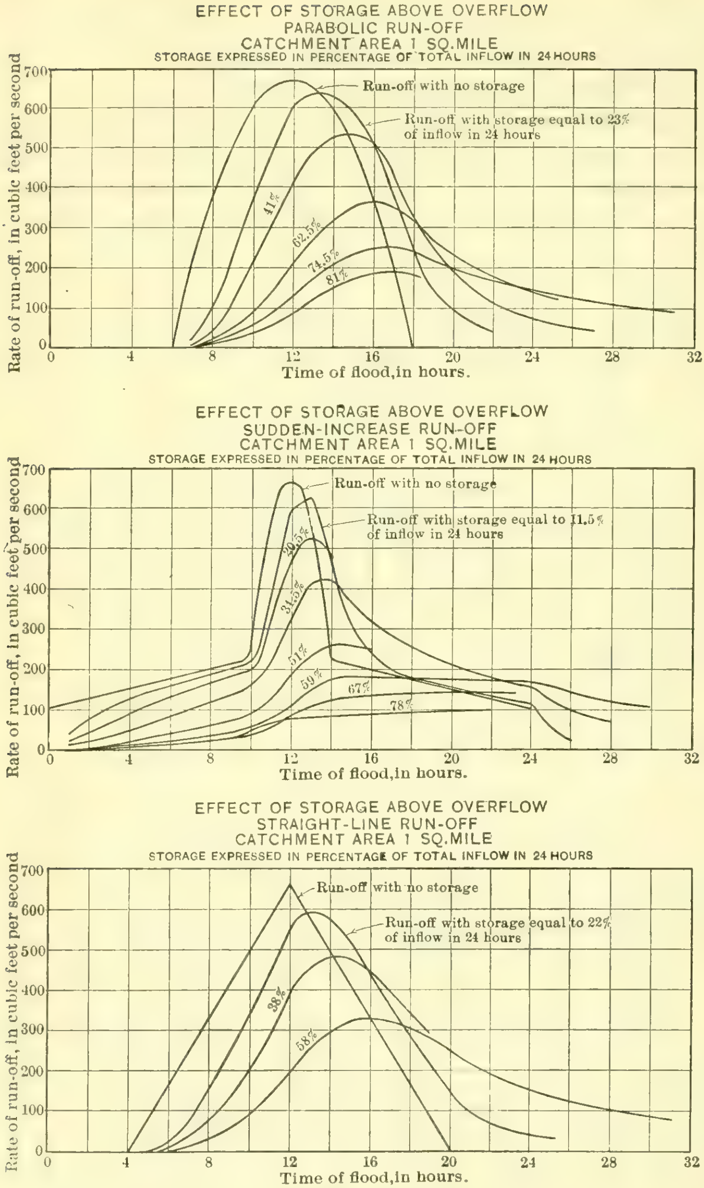

EFFECT OF STORAGE ABOVE OVERFLOW
PARABOLIC RUN-OFF
CATCHMENT AREA 1 SQ.MILE
STORAGE EXPRESSED IN PERCENTAGE OF TOTAL INFLOW IN 24 HOURS
Rate of run-off, in cubic feet per second
Time of flood, in hours.
Run-off with no storage
Run-off with storage equal to 23% of inflow in 24 hours
41%
62.5%
74.5%
81%
EFFECT OF STORAGE ABOVE OVERFLOW
SUDDEN-INCREASE RUN-OFF
CATCHMENT AREA 1 SQ.MILE
STORAGE EXPRESSED IN PERCENTAGE OF TOTAL INFLOW IN 24 HOURS
Rate of run-off, in cubic feet per second
Time of flood, in hours.
Run-off with no storage
Run-off with storage equal to 11.5% of inflow in 24 hours
20.5%
34.5%
51%
59%
67%
78%
EFFECT OF STORAGE ABOVE OVERFLOW
STRAIGHT-LINE RUN-OFF
CATCHMENT AREA 1 SQ.MILE
STORAGE EXPRESSED IN PERCENTAGE OF TOTAL INFLOW IN 24 HOURS
Rate of run-off, in cubic feet per second
Time of flood, in hours.
Run-off with no storage
Run-off with storage equal to 22% of inflow in 24 hours
38%
58%

FIG. 3.

TABLE 10.—EFFECT OF STORAGE ABOVE THE OVERFLOW OF A RESERVOIR, ON THE FLOOD FLOW.

Catchment area, in square miles.	Type of run-off.	Average area of reservoir above the overflow, in millions of square feet.	Total storage of water, in millions of cubic feet.	Total run-off in 24 hours, in millions of cubic feet.	Storage.		Rate of Flow, in Cubic Feet per Second			Percentage of maximum rate of outflow to maximum rate of inflow.
					Percentage of total run-off.	No. of hours at average rate of inflow.	Inflow.		Outflow.	
							Maximum rate.	Average rate 24 hours.	Maximum rate.	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	Parabolic....................	0.75	4.40	19.2	23	5.5	666	222	630	94.5
1	"	1.50	7.9	19.2	41	10.0	666	222	530	80
1	"	3.00	12.0	19.2	62.5	15.0	666	222	365	55
1	"	4.50	14.3	19.2	74.5	18.0	666	222	250	37.5
1	"	6.00	15.6	19.2	81	19.5	666	222	190	28.5
1	Sudden increase............	0.38	2.17	19.2	11.5	2.8	666	222	625	94
1	" "	0.75	3.9	19.2	20.5	4.9	666	222	535	80
1	" "	1.50	6.65	19.2	34.5	8.3	666	222	422	63
1	" "	3.00	9.74	19.2	51.0	12.2	666	222	265	40
1	" "	4.50	11.37	19.2	59.0	14.2	666	222	180	27
1	" "	6.00	12.9	19.2	67.0	16.1	666	222	141	21
1	" "	9.00	15.0	19.2	78.0	18.7	666	222	98	14.5
1	Straight line................	0.75	4.14	19.2	22.0	5.3	666	222	592	89
1	" "	1.5	7.22	19.2	38.0	9.1	666	222	480	72
1	" "	3.0	11.17	19.2	58.0	13.9	666	222	326	49
1	Continuous maximum......	0.75	4.47	19.2	23.5	5.6	666	222	662	99.5
1	" "	1.50	8.47	19.2	44.0	10.5	666	222	610	91.5
1	" "	3.00	12.98	19.2	67.5	16.2	666	222	410	61.5
10	Parabolic....................	4.56	26.4	120.5	22.0	5.3	2 790	1 395	2 640	94.0
10	"	9.45	48.7	120.5	40.5	9.7	2 790	1 395	2 220	79.5
100	"	15.0	89.5	765.0	11.5	2.76	13 260	8 840	13 200	99.0
100	"	30.0	173.0	765.0	22.5	5.4	13 260	8 840	12 500	94.0
100	"	60.0	308.0	765.0	40.0	9.6	13 260	8 840	10 700	81.0
1 000	"	375.0	1 965.0	4 800.0	41.0	9.8	69 300	55 500	57 000	82.0

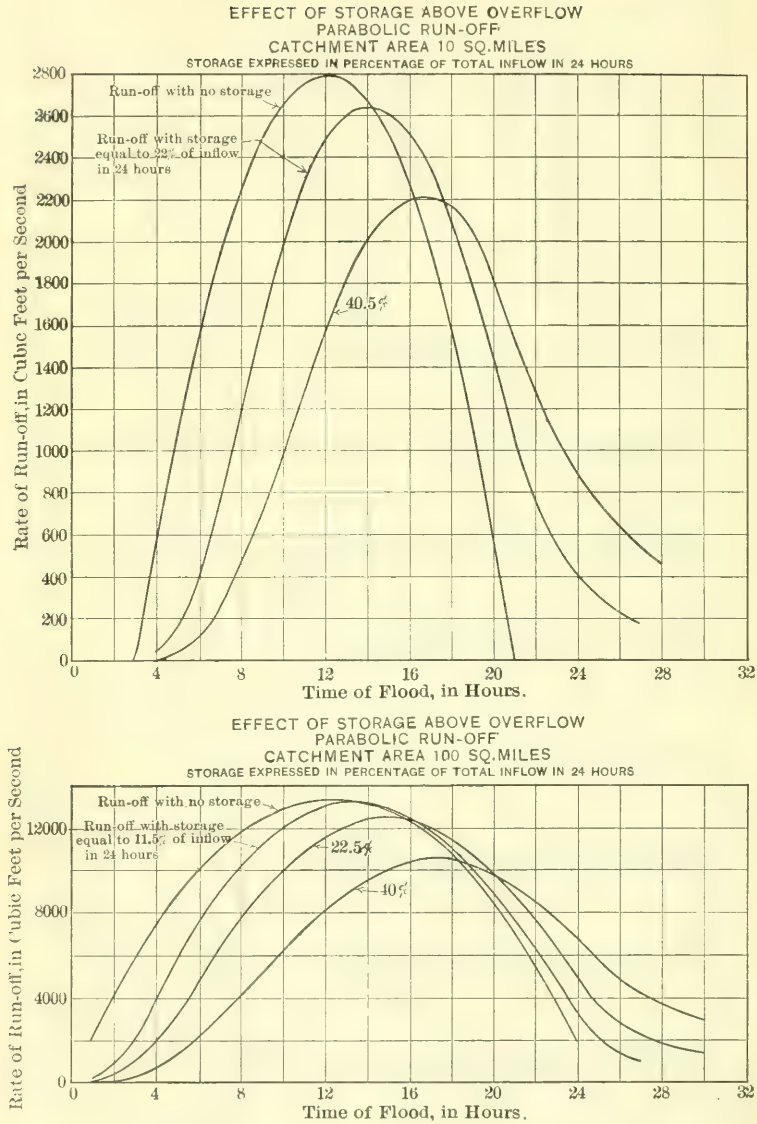

EFFECT OF STORAGE ABOVE OVERFLOW
PARABOLIC RUN-OFF
CATCHMENT AREA 10 SQ.MILES
STORAGE EXPRESSED IN PERCENTAGE OF TOTAL INFLOW IN 24 HOURS
Run-off with no storage
Run-off with storage equal to 22% of inflow in 24 hours
40.5%
Rate of Run-off, in Cubic Feet per Second
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
4
8
12
16
20
24
28
32
Time of Flood, in Hours.
EFFECT OF STORAGE ABOVE OVERFLOW
PARABOLIC RUN-OFF
CATCHMENT AREA 100 SQ.MILES
STORAGE EXPRESSED IN PERCENTAGE OF TOTAL INFLOW IN 24 HOURS
Run-off with no storage
Run-off with storage equal to 11.5% of inflow in 24 hours
22.5%
40%
Rate of Run-off, in Cubic Feet per Second
12000
8000
4000
0
0
4
8
12
16
20
24
28
32
Time of Flood, in Hours.

Fig. 4.

the magnitude of the flood. The better the hydraulic properties, the greater the relative flood flow. The chances of damage by the flood in such case, however, may be less.

Rainfall.—The annual rate of rainfall has been embodied in some flood formulas. This may be misleading, as it is the intensity and duration of the rainfall during or immediately preceding the flood that is the principal factor. Until more information is available on the rainfall conditions, as to intensity and duration, it is probable that this element is better left to judgment as to its effect on the coefficients of streams.

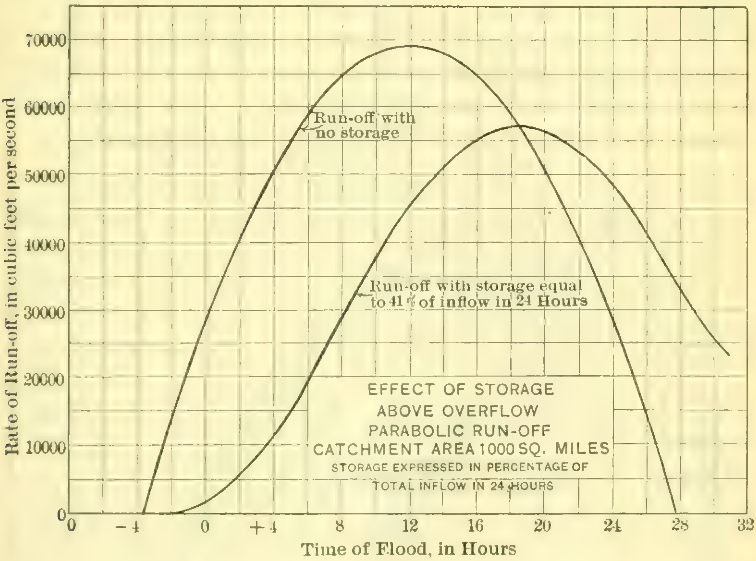


Fig. 5.

The effects of many of these factors are not the same for different floods. In some cases characteristics which would reduce the flood under average conditions tend to increase it for particular conditions. For example, it is entirely possible that storage will hold back the water on some of the branches of a river until such a time as greater quantities of water are coming from other and larger branches, thus producing a greater flood on the main stream than would have occurred if there had been no storage and the first branch had run off rapidly. Such a condition, however, is an exception, and the foregoing may be said to hold in average cases.

TABLE 11.—EFFECT OF STORAGE ABOVE THE OVERFLOW ON THE MAXIMUM RATE OF FLOW, BASED ON FIG. 6.

AMOUNT OF STORAGE.		PERCENTAGE OF MAXIMUM RATE OF OUTFLOW TO MAXIMUM RATE OF INFLOW.		
In percentage of total water flowing into reservoir in 24 hours. (1)	In hours at average rate of inflow. (2)	For a short, sharp flood. (3)	For a long-continued flood. (4)	For an average flood. (5)
8⅓	2	95	99	97
16⅔	4	85	98	94
25	6	75	97	90
33⅓	8	64	96	85
41⅔	10	59	93	75
50	12	41	85	65
58⅓	14	29	77	55
66⅔	16	22	64	45
75	18	16	56	35
83⅓	20	11	34	25

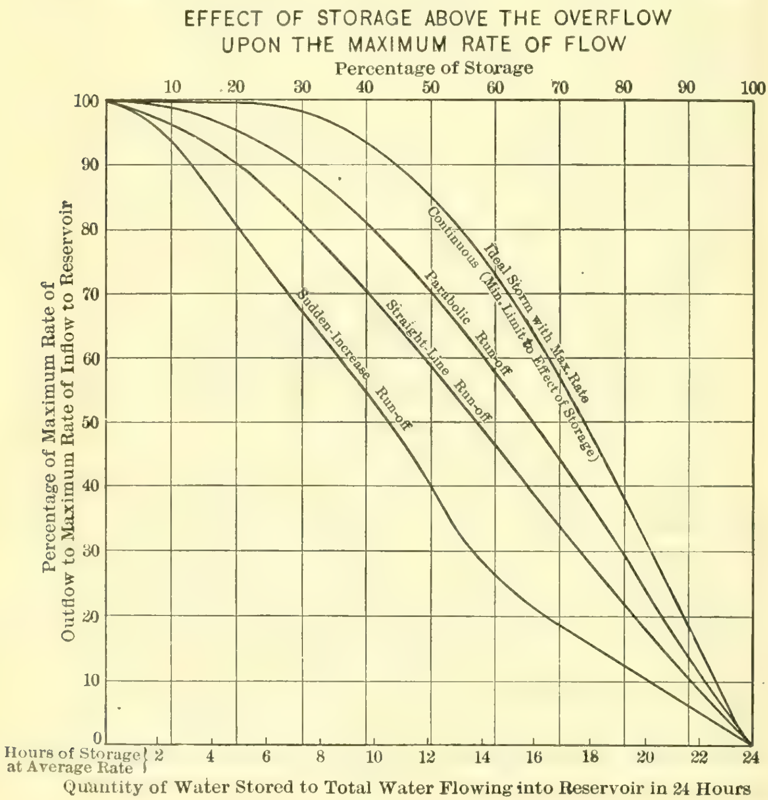


FIG. 6.

VALUES FOR THE COEFFICIENT, C, IN THE FORMULA, $Q = C\,A^{0.8}\ (1 + 0.8 \log. T)$.

Tables 12 to 26 contain flood data on the rivers in the United States for which the records could be obtained with sufficient completeness to give an approximation of the coefficient, C, in each case. Rivers for which observations are being taken at present, with records covering 4 years or more, are included, although, for these short-time periods, the value of the coefficient may be considerably in error, and should be adjusted when more complete records become available.

Each table contains a group of rivers corresponding to the classification made by the U. S. Geological Survey, and the arrangement of the rivers is similar to that given in the more recent papers of the Survey, in order that reference can readily be made thereto.

The tables contain the following data:

Column 1. Name of stream;

Column 2. Location of the station at which gaugings were taken;

Column 3. Catchment area of the stream above the point of observation, in square miles;

Column 4. Average yearly floods, obtained by selecting the one largest flood for each calendar year, and taking the average of these; this is expressed as the flow in cubic feet per second during a period of 24 consecutive hours;

Column 5. The largest flood, the second largest flood, and so on; each expressed as the flow in cubic feet per second during a period of 24 consecutive hours;

Column 6. Number of years for which the records of the single largest flood on the river could be obtained;

Column 7. Values of the coefficient in the formula, $Q = C\,A^{0.8}$ $(1 + 0.8 \log. T)$, obtained from larger floods; these values of C are only approximate, and are obtained as follows:

For the first value of C, which is obtained from the largest flood on record, T becomes equal to the length of the period of observation in years, as given in Column 7. C is then obtained by the formula,

$$C = \frac{(\text{Largest flood on record})}{A^{0.8}\ (1 + 0.8 \log. T)}, \text{ or } C = \frac{K}{(1 + 0.8 \log. T)},$$

where K is the first value for K in Column 6.

For the second value of C, Q becomes the average of the largest and the second largest floods; and the value of T becomes one-half of the period of observation, or

$$C = \frac{K + K_2}{1 + 0.8 \log. \left(\frac{1}{2} T\right)}.$$

For the third value of C, Q becomes the average of the three largest floods, and T becomes one-third the period of observation, or

$$C = \frac{K + K_2 + K_3}{1 + 0.8 \log. \left(\frac{1}{3} T\right)}.$$

Other values of C are obtained in a similar manner.

Column 8. Value of coefficient, C, as obtained from the average yearly flood; $C = \frac{Q \text{ (Ave.)}}{A^{0.8}}$.

This value of C, depending on all the yearly floods, is more accurate than those in Column 7, and should generally be selected for use.

Table 27 contains data on some of the larger single floods on rivers for which continuous records are not at hand. These data are taken from various reports and papers, and in many cases are only roughly approximate estimates. It is assumed that the flow recorded was the maximum rate, although in some instances this may not have been the case. These represent some of the greatest floods on record, but not necessarily the greatest on the stream in question for any considerable period of time. Frequently, a stream is observed for a year or so for some particular purpose, and the floods are recorded. These floods may be greater or less than the normal, but, from the fact that they are recorded, the assumption may be made that they represent the maximum floods on the stream. Tables of data of single floods may be misleading for this reason. In this study, it was in some cases found that flows taken from tables of maximum floods were actually less than the average yearly flood on the river.

Table 27 includes only the larger floods of this kind; and they probably represent one of the larger floods on that particular river.

In the following reports and papers may be found data on many rivers not here given:

Report on the Barge Canal, State of New York, 1901, page 844, Kuichling.

Hydrology of the State of New York, Rafter.

Geological Survey of New Jersey, 1904, Vermeule.

Reports of Pennsylvania Water Supply Commission.

Reports of New York State Water Supply Commission.

Reports of Maine State Water Storage Commission.

United States Geological Survey, Water Supply Paper No. 147, page 184.

United States Geological Survey, Water Supply Paper No. 162, "Destructive Floods."

Selecting the Value of T, in Design.—Floods have occurred on some rivers during the last 20 years which, normally, would be repeated in not less than 1 000 years. If works are to provide for floods equal to the greatest that have been observed, a value of T of at least 1 000 should be used. Such a flood or a greater one may occur on any river at any time, but it is not likely to come soon on any particular stream. It must be remembered that the use of $T = 1\,000$ does not mean that the corresponding flood will come at the end of 1 000 years, but that the chances are even that it will occur at some time during a period of 1 000 years. It means, also, that the chances are 1 to 1 000 that it will occur in any one year, or 1 to 100 that it will occur in 10 years, or 1 to 10 that it will occur in a century.

The selection of the proper value of T then becomes a question of what chance we can afford to take. In the design of a spillway of an earth dam, the failure of which would cause great damage, a large value of T should be used. The design of a temporary dam for construction purposes, the failure of which would mean only small damage, would call for the use of a comparatively small value of T.

The decision as to the value of T to be selected should depend on considerations of the first cost of the construction required to provide for it, together with the probable damage in case the flood exceeds the quantity provided for. The added cost due to using a larger value of T may be regarded as insurance against loss. Obviously, if insurance is costly, as compared to the risk, less should be taken. Consideration of possible loss of life and property, together with loss of business, or loss of a water supply for a city, and other factors, must be taken into account in deciding on the proper value of T. Possible increased damage in the future, due to building up of sections below the dam, or unusual difficulties in reconstruction, must be considered.

TABLE 12.—Values for Coefficient, C, in Formula, $Q = C\ A^{0.8}\ (1 + 0.8 \log. T)$. New England States.

Name of stream. (1)	Location of station. (2)	Catchment area, in square miles, A. (3)	Flood Flows, in Cubic Feet per Second. 24 Hour Average. Average yearly, Q (Ave.). (4)	Larger flood. Q. (5)	Period of observation. T. (6)	Values of C. From larger floods. (7)	From average yearly flood. (8)
St. John	Fort Kent, Me	5 280	62 500	75 600	6	49	66
Fish	Wallagrass, Me	890	7 339	8 970	5	14	17
Aroostook	Fort Fairfield, Me	2 230	30 200	34 300	6	44	63
St. Croix	Woodland, Me	1 420	9 600	20 300	9	35	29
Machias	Whitneyville, Me	465	5 740	11 100	8	47	42
Penobscot (West Branch)	Millinockett, Me	1 880	14 000	24 250	11	32	34
				22 110		36	
Penobscot	West Enfield, Me	6 600	60 630	93 400	11	44	53
				91 400		50	
Penobscot (East Branch)	Grindstone, Me	1 100	12 600	21 400	9	47	47
Mattawamkeag	Mattawamkeag, Me	1 500	16 000	24 400	9	40	46
				21 100		43	
Piscataquis	Foxcroft, Me	286	10 170	18 100	9	112	110
				13 800		114	
Kennebec	The Forks, Me	1 570	13 720	19 890	11	30	38
				18 330		33	
Kennebec	Bingham, Me	2 660	32 000	48 000	8	51	58
				37 750		53	
Kennebec	Waterville, Me	4 270	59 600	151 000	18	94	74
				111 200		93	
				86 200		89	
Roach	Roach, Me	85	1 660	1 970	7	33	47
Carrabasset	North Anson, Me	340	9 080	13 670	5	83	86
Sandy	Madison, Me	650	9 800	13 800	5	50	55
Cobbosseecontee	Gardiner, Me	240	1 850	3 275	21	20	23
				3 200		22	
				2 700		23	
Androscoggin	Rumford Falls, Me	2 090	24 900	55 500	40	53	55
				55 200		59	
				39 000		57	
Saco	Center Conway, N. H.	385	10 500	14 100	6	75	90
Pemigewasset	Plymouth, N. H.	615	16 800	30 640	24	86	99
				23 400		86	
				22 760		88	
Merrimac	Franklin Junction, N. H.	1 460	18 700	27 900	7	50	55
Merrimac	Garvins Falls, N. H.	2 340	24 600	32 900	7	39	45
Merrimac	Lawrence, Mass	4 638	43 400	82 150	56	40	50
				74 000		42	
				65 000		42	
				62 500		42	
				61 200		44	
Connecticut	Orford, Vt	3 305	31 700	49 700	11	42	49
				40 600		44	
Connecticut	Sunderland, Mass	7 700	78 700	103 000	8	47	61
				92 200		52	
Connecticut	Holyoke, Mass	8 144	73 000	115 000	26	40	54
				112 000		45	
				99 700		46	
				94 300		47	
				87 900		48	
Connecticut	Hartford, Conn	10 234	113 400	205 200	104	49	71
				192 300		52	
				178 400		54	
				175 000		55	
				169 300		56	56
				167 000		57	

TABLE 12.—(*Continued.*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Israel (above South Branch)	Jefferson Highland, N. H.	8.7	356	554	3	71	63
Israel (below South Branch)	Jefferson Highland, N. H.	21.2	721	1 050	4	61	63
Fomer	Above Reservoir,			788	14	53	56
	Holyoke, Mass	13	434	672		56	
				628		58	
Westfield Little	Blandford, Mass	43	1 420	2 135	4	71	70
Housatonic	Gaylordsville, Conn	1 020	16 000	31 000	9	69	63
				25 700		73	

TABLE 13.—VALUES OF COEFFICIENT, C,
IN FORMULA, $Q = C\ A^{0.8}\ (1 + 0.8 \log. T)$.
HUDSON RIVER BASIN.

Name of stream.	Location of station.	Catchment area, in square miles, A.	Flood Flows, in Cubic Feet per Second. 24-Hour Average.		Period of observation. T.	Values of C.	
			Average yearly. Q (Ave.).	Larger flood. Q.		From larger floods.	From average yearly flood.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Hudson	Fort Edward, N. Y.	2 800	32 900	43 900	13	40	58
				42 800		46	
				42 600		53	
Hudson	Mechanicsville, N. Y.	4 500	41 500	70 000	40	36	49
				59 400		38	
				56 300		39	
				54 900		41	
Hoosic	Buskirk, N. Y.	579	10 024	13 680	5	54	62
Mohawk	Little Falls, N. Y.	1 310	20 330	24 220	7	46	65
				23 500		53	
Mohawk	Dunsbach Ferry, N. Y.	3 440	50 500	84 200	12	68	75
				59 200		66	
				55 700		67	
West Canada Creek	TwinRock Bridge, N. Y.	364	13 050	34 350	9	171	116
				16 150		147	
East Canada Creek	Dolgeville, N. Y.	256	5 950	12 150	12	78	71
				7 540		72	
Schoharie	Prattsville, N. Y.	240	7 940	13 100	9	93	99
				12 860		107	
Esopus	Olive Bridge, N. Y.	239	8 420	15 388	7	114	105
				9 376		108	
Esopus	Kingston, N. Y.	324	13 160	20 500	9	114	129
				18 700		126	
Rondout	Rosendale, N. Y.	380	13 290	19 510	9	96	115
				18 300		107	
Reels Cr. and Johnson Br.	Durfield, N. Y.	442	243	296	4	61	74
Starch Factory	Hartford, N. Y.	3.4	351	515	4	131	132
Graefenburg Creek	Hartford, N. Y.	0.282	13.4	15.2	4	28	37

Although the selection of the proper value of T must be a matter of engineering judgment, the following method will give the economic value: Estimate the probable amount necessary to make good all damage caused by the flood exceeding the allowed amount. Multiply this by the probability of the flood occurring in one year. The product

TABLE 14.—VALUES FOR COEFFICIENT, C, IN FORMULA, $Q = C\ A^{0.8}\ (1 + 0.8 \log. T)$.

MIDDLE ATLANTIC STATES.

Name of stream.	Location of station.	Catchment area, in square miles, A.	Flood Flows, in Cubic Feet per Second. 24-Hour Average. Average yearly. Q (Ave.).	Larger flood. Q.	Period of observation. T.	Values of C. From larger floods.	From average yearly flood.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Passaic	Chatham, N. J	101	1 914	2 986	9	43	48
				2 860		48	
Passaic	Dundee Dam, N. J	823	10 600	27 995	34	58	50
				21 370		58	
				18 200		57	
				16 600		57	
						93	
Raritan	Bound Brook, N. J	800	19 700	28 500	6	83	93
Delaware (East Branch)	Hancock, N. Y	920	32 900	72 500	9	175	140
				50 500		172	
Delaware	Port Jervis, N. Y	3 250	62 500	108 000	8	98	97
				67 300			
Delaware	Riegelsville, N. J. (Former Station at Lambertville, N. J.)	6 430	99 000	176 900	15	82	89
				171 700		92	
				158 300		96	
Delaware (West Branch)	Hancock, N. Y	680	19 250	33 740	9	105	105
				31 830		117	
Musconetcong	Bloomsbury, N. J	146	1 810	2 780	4	34	34
Tohickon Creek	Point Pleasant, Pa	102	4 820	8 650	25	102	103
				6 515		101	
				5 960		101	
				5 360		101	
Neshaminy Creek	Low Forks, Pa	139	4 620	9 012	27	81	89
				8 707		90	
				6 985		90	
				6 063		88	
Perkiomen	Frederick, Pa	152	5 020	8 769	27	73	89
				7 051		74	
				6 843		77	
				6 789		79	
Schuylkill	Near Philadelphia, Pa	1 920	30 400	82 156	14	101	72
				36 600		84	
				36 180		80	
Susquehanna	Binghamton, N. Y	2 400	39 100	63 000	10	70	78
				48 900		71	
Susquehanna	Wilkes-Barre, Pa	9 810	123 800	217 700	12	75	79
				166 300		76	
				153 000		78	
Susquehanna	Danville, Pa	11 100	143 250	304 800	12	95	83
				228 400		93	
				176 000		91	
Susquehanna	Harrisburg, Pa	24 000	276 000	593 000	21	90	87
				543 000		98	
				484 000		100	
				405 000		100	
Susquehanna	McCall's Ferry, Pa	26 800	286 000	352 900	7	60	82
Chenango	Binghamton, N. Y	1 530	25 970	35 900	11	56	74
				34 600		63	
				31 200		67	
Chemung	Chemung, N. Y	2 440	35 740	46 200	7	53	69
				42 900		60	

TABLE 14.—(*Continued.*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Susquehanna (West Branch)	Williamsport, Pa.	5 640	104 300	164 100	17	82	100
				162 600		94	
				150 900		99	
Juniata	Newport, Pa.	3 480	63 500	118 000	11	95	93
				102 000		103	
Broad Creek	Millgreen, Md.	16.4	279	509	5	35	30
Gunpowder Falls	Glencoe, Md.	160	3 780	5 530	4	65	65
Little Gunpowder Falls	Bel Air, Md.	43	898	1 600	4	53	44
Patapsco	Woodstock, Md.	251	6 890	11 000	12	72	83
				9 700		77	
Potomac	Point of Rocks, Md.	9 650	114 000	218 700	17	72	67
				203 800		79	
				182 000		82	
Shenandoah	Millville, W. Va.	3 000	44 800	139 700	13	122	74
				77 900		109	
				60 800		101	
Potomac (North Branch)	Piedmont, W. Va.	410	8 110	13 450	7	65	67
Antietam Creek	Sharpsburg, Md.	295	3 240	6 835	8	42	34
				4 110		39	
Shenandoah (South Fork)	Front Royal, Va.	1 570	25 200	76 800	7	125	70
Monocacy	Frederick, Md.	660	14 800	20 460	15	59	82
				19 200		65	
				17 400		68	

is the annual value of the flood risk. Estimate the first cost of the works necessary to provide for floods of a magnitude corresponding to these values for T. Multiply this by the going rate of interest. The product is the annual interest charge. Select the value of T for which the sum of the annual value of the flood risk and the annual interest charge is a minimum.

Comparison with Other Flood Formulas.

Table 29 is a list of some other formulas for obtaining the maximum flood flow. These formulas are of different forms, and contain many different terms. Some are intended only for use over a limited section, and others are for more general use. In order to make any comparison, it is necessary to assume values for the variable terms. The values assumed are intended to suit average conditions in the eastern portion of the United States. Three of the formulas were derived for such conditions, and the others were for European and Indian conditions. For the purpose of comparison, data on some of the larger floods on foreign streams are given in Table 30. On Plate LXXI the formulas in Table 29 are plotted, together with three curves representing the formula proposed in this paper. An examination of this diagram shows that formulas vary widely. This is to

TABLE 15.—VALUES OF COEFFICIENT, C, IN FORMULA, $Q = C\ A^{0.8}\ (1 + 0.8 \log. T)$.

SOUTH ATLANTIC STATES.

Name of stream.	Location of station.	Catchment area in square miles, A.	Flood Flows, in Cubic Feet per Second. 24 Hour Average. Average yearly. Q (Ave.).	Larger flood. Q.	Period of observation. T.	Values of C. From larger floods.	From average yearly flood.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
James	Buchanan, Va	2 660	40 846	62 000	15	71	91
				52 565		78	
				51 400		82	
				48 620		86	
James	Cartersville, Va	6 230	61 658	84 800	12	42	57
				75 800		46	
James (North Fork)	Near Glasgow, Va	831	16 600	37 250	10	95	77
				24 060		100	
Appomattox	Mattoax, Va	745	8 449	11 695	4	40	43
Roanoke	Roanoke, Va	388	18 813	18 104	14	80	75
				12 472		84	
Dan	South Boston, Va	2 750	23 140	44 400	5	50	41
Cape Fear	Fayetteville, N. C	4 493	52 800	90 650	15	56	63
				71 600		60	
				69 700		64	
Yadkin	North Wilkesboro, N. C.	500	12 345	17 900	7	74	85
				15 700		82	
Yadkin	Salisbury, N. C	3 400	62 192	130 000	15	100	93
				115 000		111	
				79 998		116	
Catawba	Morganton, N. C	758	20 839	32 200	8	93	103
Catawba	Catawba, N. C	1 535	29 215	61 050	6	106	82
Catawba	Rockhill, S. C	2 987	60 000	150 783	6	154	99
Wateree	Camden, S. C	4 500	30 690	36 500	6	27	37
Broad (of the Carolines)	Alston, S. C	4 610	76 400	131 000	11	84	89
				130 500		96	
Saluda (Branch Mobile)	Waterloo, S. C	1 056	13 800	18 850	9	41	53
				18 500		47	
Tugalloo (Branch Savannah)	Madison, S. C	593	15 301	21 860	10	73	93
				17 300		80	
Savannah	Augusta, Ga	7 300	114 300	309 930	20	124	93
				253 000		133	
				220 000		130	
Tallulah	Tallulah Falls, Ga	191	4 870	9 000	7	80	73
Broad (of Georgia)	Carlton, Ga	762	20 428	47 200	13	123	101
				29 125		114	
Ocmulgee	Jackson, Ga	1 400	19 920	25 400	5	50	54
Ocmulgee	Macon, Ga	2 420	32 550	50 860	18	50	64
				46 240		55	
				43 100		57	
Oconee	Greensboro, Ga	1 100	18 540	68 200	8	145	68
Oconee	Milledgeville, Ga	2 840	16 600	30 000	5	35	29
Oconee	Dublin, Ga	4 180	29 013	37 000	13	25	37
				36 600		28	
Appalachee	Buckhead, Ga	440	5 020	7 660	8	34	39
Chattahoochee	Norcross, Ga	1 170	17 747	30 180	8	62	62
Chattahoochee	Oakdale, Ga	1 560	34 100	48 800	8	79	95
Chattahoochee	West Point, Ga	3 300	48 483	88 630	14	70	74
				66 090		75	
Soquee	Demorest, Ga	158	5 652	8 830	5	93	93
Flint	Woodbury, Ga	990	16 434	30 250	10	67	66
				25 750		75	
Flint	Montezuma, Ga	2 700	14 320	20 800	5	24	25
Flint	Albany, Ga	5 000	29 731	42 600	9	27	33
				38 970		30	

PLATE LXXI.
PAPERS. AM. SOC. C. E.
MAY, 1913.
FULLER ON
FLOOD FLOWS.

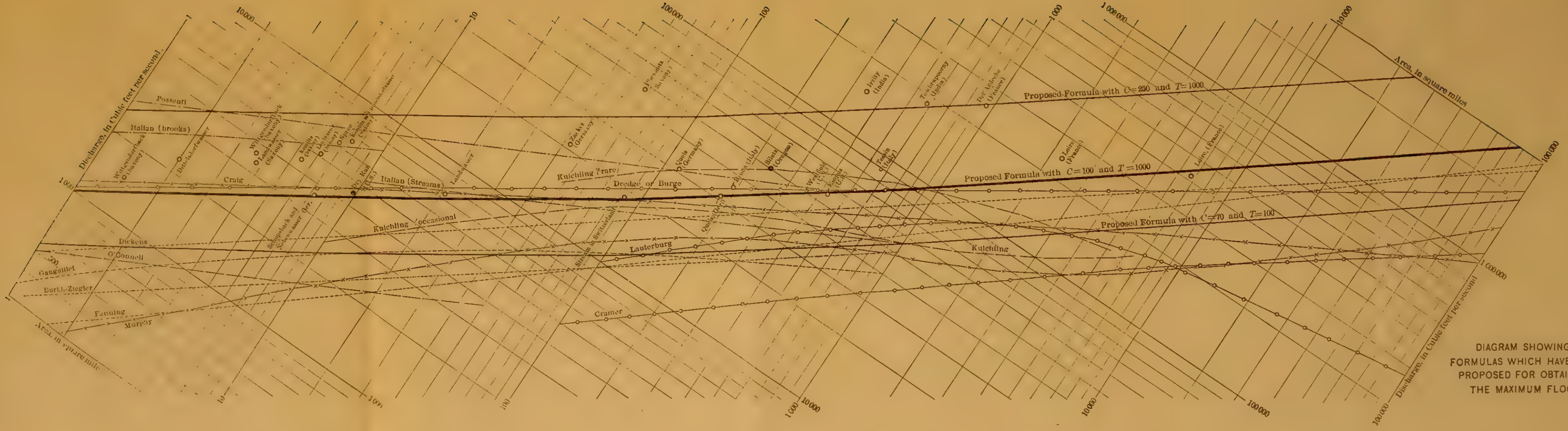


DIAGRAM SHOWING
FORMULAS WHICH HAVE BEEN
PROPOSED FOR OBTAINING
THE MAXIMUM FLOOD

TABLE 15.—(*Continued.*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Pea	Pera, Ala.	1 180	9 643	12 600	6	27	33
Conecuh	Beck, Ala.	1 290	10 600	16 400	6	33	35
Coosawattee (Branch Mobile)	Carters, Ga.	531	12 500	17 700	12	63	83
				16 950		72	
Oostanaula (Branch Mobile).	Resaca, Ga.	1 610	23 661	39 200	11	59	64
				36 600		65	
Coosa	Rome, Ga.	4 006	54 100	64 186	7	48	71
Coosa (Branch Mobile)	Riverside, Ala.	7 060	57 562	75 800	14	33	48
				75 000		38	
				72 160		41	
Alabama	Selma, Ala.	15 400	114 028	146 000	12	36	51
				145 700		40	
				138 000		44	
Etowah	Canton, Ga.	604	13 440	19 000	12	61	80
				17 090		68	
				16 094		72	
Etowah	Rome, Ga.	1 800	35 200	59 400	6	91	87
Choccolocco Creek	Jenifer, Ala.	272	5 110	11 800	4	90	58
Tallapoosa	Sturdevant, Ala.	2 500	36 247	59 100	10	63	69
				50 800		70	
				40 510		69	
Cahaba	Centerville, Ala.	1 040	11 981	17 100	6	41	46
				12 980		42	
Tombigbee	Columbus, Miss.	4 440	34 476	50 420	10	34	41
				46 800		39	
				40 498		39	
Tombigbee	Epes, Ala.	8 830	44 887	61 000	8	25	31
				50 500		28	
Black Warrior	Cordova, Ala.	1 900	42 100	56 900	9	77	100
				51 800		87	
Black Warrior	Tuscaloosa, Ala.	4 900	101 000	141 000	17	79	113
				137 000		89	
				129 000		97	
Pearl	Jackson, Miss.	3 120	21 649	36 500	8	34	35

be expected as the data on which they are based are very different. On the whole, it may be said that the formula proposed in this paper gives relatively higher values of the flood flow for very small and very large catchment areas. Probably the reason for this is that the formula was derived from average floods, and many, if not all, of the others were derived from maximum floods. There are numerous records for medium-sized streams, but not for very small or very large ones. It is to be expected, under these conditions, that the highest relative maximum floods will be found on rivers of medium size. There are comparatively few very large rivers in Europe, and their number in America is limited. Although there are many small streams, damage from flood on them is not usually great, and records of their floods are comparatively few. More records of small streams are probably available on European than on American rivers.

Some of the largest floods on foreign and American streams are plotted on Plate LXXI. The largest of these are on streams in India and Saxony. The upper curve, representing the proposed formula,

TABLE 16.—VALUES FOR COEFFICIENT, C, IN FORMULA, $Q = C\,A^{0.8}\ (1 + 0.8 \log. T)$.

OHIO RIVER BASIN.

Name of stream.	Location of station.	Catchment area, in square miles, A.	Flood Flows, in Cubic Feet per Second. 24-Hour Average. Average yearly. Q (Ave.).	Larger flood. Q.	Period of observation. T.	Values of C. From larger floods.	From average yearly flood.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Allegheny	Red House, N. Y.	1 640	25 200	41 000	8	64	67
Allegheny	Kittanning, Pa	8 690	126 000	232 000	7	97	88
Kiskiminetis	Avonmore, Pa	1 750	46 400	77 700	4	133	118
Blacklick Creek	Blacklick, Pa	403	9 668	15 400	7	75	79
Cheat	Morganton, W. Va	1 380	19 540	30 400	8	54	60
				25 900		59	
Youghiogheny	Friendsville, Md	294	6 660	8 160	6	54	71
Youghiogheny	Confluence, Pa	435	11 580	24 000	8	108	90
Casselman	Confluence, Pa	450	10 250	20 800	6	96	77
Laurel Hill Creek	Confluence, Pa	118	2 851	5 020	5	74	67
Mahoning	Youngstown, Ohio	958	14 911	19 400	4	54	61
New	Radford, Va	2 720	64 200	137 760	13	130	115
				123 800		142	
New	Fayette, W. Va	6 200	78 155	110 527	7	61	72
				107 740		70	
Greenbrier	Alderson, W. Va	1 340	36 900	62 450	14	103	117
				55 850		111	
				48 700		115	
Scioto	Columbus, Ohio	1 050	14 515	21 340	5	53	56
French Broad	Asheville, N. C	987	16 400	30 720	11	67	65
				26 350		71	
Tennessee	Knoxville, Tenn	8 990	92 891	157 410	10	60	64
				124 070		62	
Tennessee	Chattanooga, Tenn	21 400	231 000	409 520	21	68	79
				381 040		74	
				363 240		78	
				363 240		82	
Mill (North Fork)	Pinkbed, N. C	24	763	1 170	4	62	60
Mill (South Fork)	Sitton, N. C	40.5	1 562	2 050	4	72	81
Pigeon	Newport, Tenn	655	10 314	20 260	7	67	57
				12 300		63	
Nolichucky	Greeneville, Tenn	1 100	14 093	32 300	6	74	52
				18 900		69	
Holston (South Fork)	Bluff City, Tenn	828	20 130	32 980	6	93	92
				24 380		94	
Holston	Rogersville, Tenn	3 060	37 400	51 400	5	53	60
Watauga	Elizabethton, Tenn	408	6 013	9 530	4	52	49
Little Tennessee	Judson, N. C	675	25 800	57 140	14	163	142
				50 460		180	
Little Tennessee	McGhee, Tenn	2 470	37 240	70 000	6	73	63
Tuckaseegee	Bryson, N. C	662	22 500	38 550	13	113	124
				36 400		125	
Hiwassee	Murphy, N. C	410	12 300	22 360	13	96	101
				22 000		110	
Hiwassee	Reliance, Tenn	1 180	28 550	55 200	10	109	101
				38 000		106	
Hiwassee	Charleston, Tenn	2 297	37 055	45 940	4	63	76
Valley	Tomotla, N. C	106	4 842	10 400	5	160	117
Nottenly	Ranger, N. C	272	4 122	5 660	5	41	47
Toccoa	Blue Ridge, Ga	231	7 958	12 290	5	102	102
Ocoee	McCays, Copperhill, Tenn	374	7 000	18 000	6	97	61
Elk	Elkmont, Ala	1 700	39 750	49 000	4	86	103

TABLE 16.—(*Continued.*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dock	Columbia, Tenn	1 260	18 660	25 600	5	55	62
Clarion	Clarion, Pa	910	23 280	39 300	20	82	98
				36 000		89	
				34 200		94	
				32 700		97	
Ohio	Wheeling, W. Va	23 800	294 000	480 000	50	65	93
				460 000		70	
				430 000		67	
				428 000		67	
				428 000		69	

TABLE 17.—VALUES FOR COEFFICIENT, C, IN FORMULA, $Q = C\ A^{0.8}\ (1 + 0.8 \log. T)$.

ST. LAWRENCE RIVER BASIN.

Name of stream. (1)	Location of station. (2)	Catchment area, in square miles, A. (3)	Flood Flows, in Cubic Feet per Second. 24-Hour Average. Average yearly Q (Ave.). (4)	Larger flood. Q. (5)	Period of observation. T. (6)	Values of C. From larger floods. (7)	From average yearly flood. (8)
Dead	Forestville, Mich	142	2 270	2 340	4	30	43
Escanaba	Escanaba, Mich	800	7 340	10 870	7	31	35
Menominee	Iron Mountain, Mich	2 420	11 180	15 100	9	16.8	22
				15 000		19.4	
St. Joseph	Buchanan, Mich	3 940	11 100	18 600	5	15.8	14.8
				11 470		15.2	
Kalamazoo	Allegan, Mich	1 470	4 700	10 260	6	18.5	13.7
				5 219		16.4	
Muskegon	Newaygo, Mich	2 350	4 740	6 266	4	8.4	9.5
Manistee	Sherman, Mich	900	2 380	2 870	8	7.2	10.3
Thunder Bay	Alpena, Mich	1 260	5 400	7 275	7	14.3	17.8
Au Sable	Bamfield, Mich	1 420	3 470	4 220	6	7.9	10.4
Huron	Geddes, Mich	757	2 290	3 734	7	11.1	11.4
Huron	Flat Rock, Mich	1 000	2 310	2 780	7	6.6	9.2
Seneca	Baldwinsville, N. Y	3 100	8 846	10 865	8	10.2	14
				10 310		11.5	
Oneida	Euclid, N. Y	1 310	9 983	13 760	7	26	32
Chittenango Creek	Chittenango, N. Y	79	1 390	1 922	5	37	42
Salmon	Pulaski, N. Y	259	9 310	10 500	5	79	110
Black	Felts Mills, N. Y	1 850	18 270	23 100	9	32	44
				19 200		35	
Moose	Moose River, N. Y	346	5 780	6 760	11	35	54
				6 670		40	
Oswegatchie	Ogdensburg, N. Y	1 580	11 990	15 800	8	26	33
Raquette	Massena Springs, N. Y.	1 170	8 540	11 000	8	21	30
				9 920		26	
Saranac	Plattsburg, N. Y	624	4 120	4 680	6	16.6	24
Winooski	Richmond, Vt	885	12 225	16 300	4	48	53
Genesee	Rochester, N. Y	2 365	22 100	50 000	128	37	44
				40 000		37	
				36 500		38	
				36 000		37	
				36 000		37	
				33 000		37	
Genesee	Rochester, N. Y	2 365	22 400	36 500	12	39	45
				36 000		45	
				28 300		45	
				28 000		47	

TABLE 18.—VALUES FOR COEFFICIENT, C, IN FORMULA, $Q = C\ A^{0.8}\ (1 + 0.8 \log. T)$.

HUDSON BAY.

Name of stream.	Location of station.	Catchment area, in square miles, A	Flood Flows. in Cubic Feet per Second. 24-Hour Average. Average yearly. $\bar{Q}$ (Ave.).	Larger flood. Q.	Period of observation. T.	Values of C. From larger floods.	From average yearly flood.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
St. Mary (above Swiftcurrent Creek)	Near Babb, formerly Main, Mont	177	3 897	7 980	9	72	54
				4 360		64	
St. Mary	Near Cardston, Alta	452	5 945	18 000	8	79	45
				6 175		61	
Swiftcurrent Creek	Near Babb, Mont	101	2 248	4 540	9	65	51
				3 360		65	
Ottertail (head of Red)	Near Fergus Falls, Minn	1 310	813	1 075	7	2.0	2.6
Red	Fargo, N. Dak	6 020	3 086	6 089	9	3.2	2.9
				4 420		3.2	
Red	Grand Forks, N. Dak	25 000	21 706	32 920	8	5.8	6.6
				29 400		6.4	
Sheyenne	Haggart. N. Dak	5 400	1 300	2 030	5	1.3	1.3
Red Lake	Crookston, Minn	5 320	8 669	14 200	8	8.6	9.1
Pembina	Neche, N. Dak	2 940	1 938	3 870	7	3.9	3.3

with $C = 250$ and $T = 1\,000$, covers all except two of these floods. There is no record of any American flood as large as these, although the record of the Siletz River, covering a 3-year period, includes one of great magnitude; the maximum rate is not stated, but the 24-hour average rate is relatively greater than that of any flood recorded on any other American stream. It is stated by the U. S. Geological Survey that this stream is typical of those in that section of Oregon, and it seems probable that floods there equal or exceed those on foreign rivers. It is also probable that other floods for which no records are available have exceeded any of those recorded.

On the lower diagram of Plate LXIX is plotted the larger floods on the rivers in the eastern part of the United States. The two curves drawn to represent the formula, with $C = 100$, $T = 1\,000$, and $C = 100$, $T = 50$, cover these great floods well. These may be considered as extraordinary floods on streams which usually give large floods. These few floods represent the largest ones on many rivers during the last 50 or 100 years, so that some of them may be those

TABLE 19.—VALUES OF COEFFICIENT, C, IN FORMULA, $Q = C\ A^{0.8}\ (1 + 0.8 \log. T)$.

UPPER MISSISSIPPI RIVER BASIN.

Name of stream. (1)	Location of station. (2)	Catchment area, in square miles, A. (3)	Flood Flows, in Cubic Feet per Second. 24 Hour Average. Average yearly. Q (Ave.). (4)	Larger flood. Q. (5)	Period of observation. T. (6)	Values of C. From larger floods. (7)	From average yearly flood. (8)
Mississippi	Above Sandy River, Minn.	4 510	6 250	9 572	15	5.9	7.4
				8 823		6.5	
				8 299		6.8	
Mississippi	Sauk Rapids, Minn........	12 400	32 400	51 000	3	19.6	17
Mississippi	Anoka, Minn..............	17 100	31 450	44 300	6	11.2	13
				36 600		12.0	
Mississippi	St. Paul, Minn.............	35 700	42 223	80 800	19	9.2	9.7
				73 000		9.9	
				59 800		10.0	
				58 800		10.0	
Pine	Below Pine River Reservoir, Minn.	452	1 051	1 586	16	6.1	7.9
				1 520		6.8	
				1 479		7.3	
Minnesota.........	Mankato, Minn............	14 600	24 035	43 800	8	11.6	11.0
Chippewa	Chippewa Falls, Wis......	5 300	36 454	64 400	11	37	38
				45 900		36	
Chippewa	Eau Claire, Wis...........	6 740	43 105	60 520	6	32	37
Flambeau.........	Ladysmith, Wis...........	2 120	10 079	12 750	4	18.9	21
Black.............	Neillsville, Wis...........	675	10 000	23 060	4	85	55
Wisconsin.........	Merrill, Wis...............	2 630	14 907	18 140	6	21	27
Wapsipinicon	Stone City, Iowa..........	1 310	6 395	8 690	6	17.3	20
				8 190		19.7	
Iowa..............	Iowa City, Iowa...........	3 320	12 067	19 450	4	20.0	18.3
Cedar.............	Cedar Rapids, Iowa.......	6 320	31 093	52 450	6	29.0	28
Des Moines........	Keosauqua, Iowa	14 300	61 747	97 140	4	31	29
Illinois............	Peoria, Ill.................	13 200	41 060	57 650	4	19.4	21

which would normally occur in very long periods, and others may be floods on rivers having coefficients greater than 100, which would normally occur in shorter periods. When it is considered that the formula was obtained from data independent of these floods, the agreement is noticeably close, and serves as a valuable check on the formulas here proposed.

Comparison with Flows in Sewers.—In Table 28 is given a comparison of the proposed formula with that of McMath for obtaining the flow in sewers, $Q = C\ R\ \sqrt[5]{S\ A^4}$. In making the comparison, a period of 20 years is assumed, as it seems that sewers liberally designed should flow at full capacity at least once during such a period. For the proposed formula, C is taken as 65, which is the

TABLE 20.—VALUES OF COEFFICIENT, C, IN FORMULA, $Q = C\ A^{0.8}\ (1 + 0.8 \log. T)$. MISSOURI RIVER BASIN.

Name of stream. (1)	Location of station. (2)	Catchment area, in square miles, A. (3)	Flood Flows, in Cubic Feet per Second. 24-Hour Average. Average yearly, Q (Ave.). (4)	Larger flood. Q. (5)	Period of observation. T. (6)	Values of C. From larger floods. (7)	From average yearly flood. (8)
Jefferson (continuation of Redrock and Beaverhead)	Sappington, Mont	8 984	9 860	15 470	9	6.4	6.7
				10 040		6.0	
Missouri	Townsend, Mont	14 500	28 050	52 500	8	14.3	13.2
				32 500		13.5	
Missouri	Cascade, Mont	18 300	23 524	49 300	9	10.9	9.1
				38 000		11.2	
Madison	Red Bluff, Mont	2 085	6 500	10 275	13	12.1	14.4
				8 613		12.7	
				8 325		13.2	
West Gallatin (head of Gallatin)	Salesville, Mont	860	5 800	10 750	15	25	26
				9 700		28	
				7 810		27	
Gallatin	Logan, Mont	1 805	4 860	6 550	9	9.2	12.1
				6 460		10.7	
Middle Creek	Bozeman, Mont	26	456	806	5	38	34
Ford Creek	Augusta, Mont	18	403	720	5	42	37
Smith Creek	Augusta, Mont	26	587	806	3	43	43
Marias	Shelby, Mont	2 610	11 530	29 500	6	34	21
Milk	Havre, Mont	7 300	3 919	9 600	13	4.1	3.2
				8 960		4.5	
Milk	Malta, Mont	14 000	7 040	11 200	6	3.3	3.4
Yellowstone	Livingston, Mont	3 580	19 330	26 820	9	22	27
				26 525		25	
Yellowstone	Glendive, Mont	66 100	69 275	90 600	8	7.3	9.7
				86 400		8.3	
Boulder (West Fork)	Bruffeys, Mont	94	1 528	1 610	5	27	40
Clark Fork	Fromberg, Mont	2 500	8 200	10 800	4	13.9	15.6
Pryor Creek	Huntley, Mont	800	597	1 370	5	4.2	2.4
Bighorn	Thermopolis, Wyo	8 184	13 900	17 610	6	8.0	10.3
Bighorn	Hardin, Mont	20 700	28 207	40 800	7	8.5	9.9
Shoshone	Cody, Wyo	1 480	11 330	15 800	7	27	33
Shoshone (South Fork)	Marquette, Wyo	500	3 583	5 300	5	24	25
Clear Creek	Buffalo, Wyo	118	710	853	6	11.6	15.6
Little Muddy	Williston, N. Dak	800	1 656	4 340	5	13.2	7.9
Little Missouri	Medora, N. Dak	5 780	9 588	19 000	6	11.6	9.4
Knife	Broncho, N. Dak	1 260	1 940	3 500	7	6.9	6.4
Heart	Richardton, N. Dak	1 250	3 426	8 020	8	15.5	11.4
Cannon Ball	Stevenson, N. Dak	3 650	3 480	5 900	6	5.1	4.9
Cheyenne	Edgemont, S. Dak	7 350	7 600	10 960	4	6.0	6.1
Rapid Creek	Rapid, S. Dak	410	600	880	4	4.9	4.9
Belle Fourche	Belle Fourche, S. Dak	3 250	4 050	5 941	4	6.2	6.3
Niobrara	Valentine, (Fort Niobrara), Nebr	6 070	3 749	7 000	5	3.4	3.5
North Platte	Pathfinder, Wyo	12 000	10 800	12 800	4	4.7	5.9
North Platte	Orin Junction, Wyo	14 828	17 520	22 960	4	7.6	8.1
North Platte	Guernsey, Wyo	16 200	14 500	30 000	8	7.5	6.2
				15 200		6.5	
North Platte	Mitchell, Nebr	24 400	14 227	23 000	9	4.1	3.8
				23 000		4.7	
North Platte	Camp Clark, Nebr	24 830	16 560	23 560	4	4.9	5.1

TABLE 20.—(*Continued.*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
North Platte	Bridgeport, Nebr	23 200	13 258	19 700	5	4.0	4.3
North Platte	North Platte, Nebr	28 500	17 640	25 500	13	3.7	4.8
				23 720		4.1	
				23 010		4.3	
Platte	Lexington, Nebr	53 300	19 000	30 000	5	3.1	3.1
Platte	Columbus, Nebr	56 900	25 000	51 100	14	4.2	3.9
				35 400		4.1	
				30 200		4.0	
Laramie	Woods Landing, Wyo	435	3 130	4 502	5	22	24.3
South Platte (South Fork)	South Platte, Colo	2 160	1 129	1 800	6	2.4	2.4
South Platte (South Fork)	South Platte, Colo	2 610	1 454	2 540	9	2.7	2.7
				2 170		2.9	
South Platte (South Fork)	Denver, Colo	3 840	1 900	5 570	11	4.1	2.6
				2 425		3.4	
				2 308		3.2	
South Platte	Hersey, Colo	9 470	4 150	9 335	7	3.7	2.3
South Platte	Orchard, Colo	12 260	5 875	11 159	4	4.1	3.2
South Platte	Julesburg, Colo	20 600	5 134	12 900	8	2.6	1.8
Bear Creek	Morrison, Colo	170	370	737	6	7.5	6.1
Bear Creek	Forkscreek, Colo	345	1 291	2 260	12	11.4	12.1
				1 994		12.3	
St. Vrains Creek	Lyons, Colo	209	982	1 280	10	9.9	
				1 145		10.8	13.8
Boulder Creek	Boulder, Colo	179	720	840	9	7.5	11.3
				826		8.6	
South Boulder	Marshall, Colo	125	580	1 090	7	13.7	12.2
Big Thompson Creek	Loveland, Colo	305	1 120	2 090	9	12.2	11.5
				1 685		13.8	
Cache la Poudre	Fort Collins, Colo	1 060	3 133	5 611	12	11.5	11.9
				5 100		12.5	
Loupe	Columbus, Nebr	13 500	14 940	27 000	12	7.2	7.4
				25 800		8.1	
North Loupe	St. Paul, Nebr	4 024	5 080	7 500	5	6.3	6.6
Elkhorn	Norfolk, Nebr	2 474	3 040	8 000	7	9.2	5.9
Elkhorn	Arlington, Nebr	5 980	6 300	9 568	5	5.8	6.0
Republican	Bostwick, Nebr	23 300	8 038	24 500	7	4.7	2.6
Republican	Superior, Nebr	22 347	6 450	14 100	7	2.8	2.1
Republican	Junction, Kans	25 840	20 650	47 520	11	7.8	6.1
				37 500		7.9	
Kansas	Lecompton, Kans., and Lawrence, Kans.	58 550	81 000 59 300	221 000	60 15	13.9 17.5	9.1 12.4
		and		130 000		15.8	
				81 400		14.2	
		59 841		67 000		13.2	
Saline	Saline, Kans	3 311	4 200	7 895	7	7.1	6.4
Solomon	Niles, Kans	6 815	5 400	10 602	7	5.4	4.6
Blue	Manhantan, Kans	9 490	27 500	68 770	11	25	18.1
				43 430		23	
Gasconade	Arlington, Mo	2 720	27 327	44 960	4	54	49

average coefficient for eastern rivers. For the McMath formula, values are assumed as follows: $C = 0.50$, $R = 2.75$ in.; $S = 10$ to 30. These values seem reasonable when it is considered that, during a period of 20 years, an unusually heavy rainfall would probably come on frozen or well-saturated ground, for which the percentage of run-off would be as great as, or greater than, it would be from a 50% impervious area in a city. Table 28 indicates that the flows for small catchment areas, as obtained by the proposed formula, are fairly consistent with sewer experience.

TABLE 21.—Values for Coefficient, C, in Formula, $Q = C A^{0.8}$ $(1 + 0.8 \log. T)$.

Lower Mississippi River Basin.

Name of stream.	Location of station.	Catchment area, in square miles, A.	Flood Flows, in Cubic Feet per Second. 24 Hour Average. Average yearly. Q (Ave.).	Larger flood. Q.	Period of observation. T.	Values of C. From larger floods.	From average yearly flood.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Arkansas	Salida, Colo.	1 160	2 808	3 900	7	8.2	9.9
Arkansas	Canon City, Colo.	3 060	3 757	6 690	27	5.1	6.0
				5 611		5.3	
				5 400		5.5	
				5 120		5.6	
				4 925		5.7	
Arkansas	Pueblo, Colo.	4 600	5 430	11 060	19	6.4	6.7
				8 321		6.3	
				7 659		6.5	
				6 980		6.5	
Arkansas	Nepesta, Colo.	9 130	8 996	15 075	5	6.6	6.1
Arkansas	Hutchinson, Kans.	34 000	7 296	11 645	6	1.7	1.7
Purgatory	Trinidad, Colo.	742	2 573	4 600	5	14.9	13
Verdigris	Liberty, Kans.	3 067	31 881	41 450	8	37	52
				36 950		38	
Neosho	Iola, Kans.	3 670	31 429	45 560	7	38	44
				39 120		42	

TABLE 22.—Values of Coefficient, C, in Formula, $Q = C A^{0.8}$ $(1 + 0.8 \log. T)$.

Western Gulf of Mexico.

Name of stream.	Location of station.	Catchment area, in square miles, A.	Flood Flows, in Cubic Feet per Second. 24-Hour Average. Average yearly. Q (Ave.).	Larger flood. Q.	Period of observation. T.	Values of C. From larger floods.	From average yearly flood.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Brazos	Waco, Tex.	30 800	55 000	132 000	11	18.4	14.1
				99 000		18.5	
Colorado	Austin, Tex.	37 000	43 000	72 600	10	8.9	9.5
				70 300		10.1	
Rio Grande	Del Norte, Colo.	1 400	4 350	7 670	17	11.8	13.2
				6 870		12.7	
				5 930		13.0	
				5 650		13.3	
Conejos	Mogote, Colo.	282	2 800	4 170	5	29	31

TABLE 23.—VALUES OF COEFFICIENT, C, IN FORMULA, $Q = C\ A^{0.8}\ (1 + 0.8 \log. T)$.

COLORADO RIVER BASIN.

Name of stream.	Location of station.	Catchment area, in square miles, A.	Flood Flows, in Cubic Feet per Second. 24 Hour Average. Average yearly, Q (Ave.).	Larger flood, Q.	Period of observation, T.	Values of C. From larger floods.	From average yearly flood.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Green (head of Colorado)	Green River, Wyo.	7 450	14 100	21 384	9	9.7	11.3
				17 860		10.3	
Green	Greenriver, Utah	38 200	42 200	62 400	6	8.3	9.1
Colorado	Yuma, Ariz.	225 000	90 750	149 500	9	4.4	4 7
				116 000		4.5	
Yampa	Craig, Colo.	1 730	8 740	9 680	4	16.8	22
White	Meeker, Colo.	634	3 162	3 710	5	13.6	18.1
Duchesne	Myton, Utah	2 750	5 550	9 560	9	9.5	9.7
				7 320		9.7	
Lake Fork	Myton, Utah	475	2 250	3 000	7	12.9	16.3
Uinta	Whiterocks, Utah	218	1 050	1 430	5	12.4	14.2
Uinta	Fort Duchesne, Utah	672	2 850	4 520	8	14.3	15.5
				4 470		16.5	
Whiterocks	Whiterocks, Utah	114	676	1 146	5	16.6	15.4
Grand	Kremmling, Colo.	2 380	10 750	15 300	6	18.9	21
Grand	Glenwood Springs, Colo.	4 520	20 500	27 710	8	19.2	24
				27 600		22.3	
Grand	Palisades, Colo.	8 550	26 725	37 000	7	15.7	19
Frazier	Granby (Coulter), Colo.	220	1 725	1 860	4	16.7	23
Williams Fork	Sulphur Springs, Colo.	200	1 077	1 410	5	13.1	15.6
Blue	Kremmling, Colo.	700	5 200	6 020	4	27	27
				1 190		22	
Eagle	Gypsum, Colo.	800	4 700	6 040	5	22	22
						18	
Uncompahgre	Montrose, Colo.	565	1 630	2 070	5	8.4	10.2
Dolores	Dolores, Colo.	524	2 035	2 944	8	11.4	13.5
				2 825		13.0	
Animas	Durango, Colo.	812	4 700	7 800	7	22	22
				5 870		22	
Animas	Aztec, N. Mex.	1 300	6 510	12 500	5	26	21
Gila	San Carlos, Ariz.	13 460	5 947	8 500	6	2.6	3.0
Salt	McDowell, Ariz.	6 260	43 800	138 000	6	78	40
Verde	McDowell, Ariz.	6 000	47 740	60 000	4	39	46

By grouping rivers according to their values of C, and investigating the rainfall conditions, storage, slopes, amount of sandy area, etc., for these different groups, it seems probable that much valuable information could be obtained with the data now available.

The writer feels that the method of rating and comparing rivers by using the average yearly floods affords a means of obtaining valuable information on many rivers with a comparatively small amount of labor, and hopes that in the future the maximum flood for each year will be observed for many more rivers. It is also to be hoped that

TABLE 24.—VALUES OF COEFFICIENT, C,

IN FORMULA, $Q = C\ A^{0.8}\ (1 + 0.8 \log. T)$.

GREAT BASIN.

Name of stream. (1)	Location of station. (2)	Catchment area, in square miles, A. (3)	FLOOD FLOWS, IN CUBIC FEET PER SECOND. 24-HOUR AVERAGE. Average yearly. Q (Ave.). (4)	Larger flood. Q. (5)	Period of observation. T (6)	VALUES OF C. From larger floods. (7)	From average yearly flood. (8)
Bear	Dingle, Idaho	2 890	2 670	4 050	7	4.1	4.5
				3 990		4.8	
Bear	Preston, Idaho	4 500	4 580	8 500	20	5.1	5.5
				7 900		5.5	
				6 380		5.5	
				6 100		5.6	
Bear	Collinston, Utah	6 000	6 550	11 600	21	5.3	6.1
				10 590		5.7	
				10 200		6.1	
				82 200		6.1	
Logan	Logan, Utah	218	1 390	2 450	12	17.8	18.8
				1 930		18.3	
				1 823		18.9	
Black Fork	Hyrum, Utah	286	670	1 900	9	11.7	7.3
				956		10.2	
Weber	Oakley, Utah	163	2 730	4 010	6	50	5.5
Weber	Devils Slide, Utah	1 090	4 300	5 880	4	14.1	16.0
Weber	Plain City, Utah	2 060	5 030	7 580	4	11.3	11.2
Weber	Uinta, Utah	1 600	4 800	7 980	10	12.6	13.1
				7 230		13.3	
American Fork	American Fork, Utah	66	400	885	5	20	14.3
Big Cottonwood	Salt Lake City, Utah	48.5	460	835	11	21	21
				793		23	
Mill Creek	Salt Lake City, Utah	21.3	56	112	12	5.2	4.8
				72		4.9	
Parley's Creek	Salt Lake City, Utah	50.1	142	274	12	6.4	6.3
				228		6.8	
Emigration Creek	Salt Lake City, Utah	29	18	24	8	0.9	1.2
				22		1.0	
City Creek	Salt Lake City, Utah	19.2	82	164	11	8.5	7.7
				132		8.8	
Provo	Provo, Utah	640	2 130	4 150	18	11.8	12.1
				3 620		12.5	
				3 310		12.9	
				2 600		12.7	
Hobble Creek	Springville, Utah	120	334	820	6	11.0	7.2
Spanish Fork	Spanish Fork, Utah	670	860	1 970	9	6.1	4.6
Sevier	Marysvale, Utah	2 560	1 370	3 000	6	3.5	2.6
Sevier	Gunnison, Utah	3 990	1 095	2 240	9	1.6	1.4
Sevier	Leamington, Utah	5 595	1 560	2 329	4	1.6	1.5
San Pitch	Gunnison, Utah	836	210	338	5	1.0	1.0
Humboldt	Golconda, Nev	10 800	1 400	3 160	15	0.9	0.8
				3 100		1.0	
				3 080		1.1	
Humboldt	Oreana, Nev	13 800	1 260	3 047	14	0.8	0.6
				2 616		0.8	
Humboldt (North Fork)	Halleck, Nev	1 020	530	1 020	6	2.5	2.0
Humboldt (South Fork)	Elko, Nev	1 150	1 120	1 478	13	2.8	4.0
				1 400		3.1	
				1 385		3.3	
Humboldt	Elko, Nev	2 840	1 650	2 396	7	2.5	2.8
Humboldt	Palisade, Nev	5 010	1 834	2 620	4	1.9	2.0

TABLE 24.—(*Continued.*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Truckee..............	Tahoe, Cal..................	519	774	1 340 931	10	5.0 4.9	5.2
Truckee..............	State Line, Col.-Nev......	955	5 260	15 300 8 110	10	35 31	22
Truckee..............	Vista, Nev.................	1 520	4 930	8 940 7 510	10	14.2 15.0	14.1
Walker (West Fork).	Coleville, Cal..............	306	2 300	4 170	6	26	24
Walker...............	Yerington, Nev............	1 100	700	1 700	7	3.8	2.6
Donner Creek.........	Truckee, Cal..............	30	560	980 862	8	38 41	37
Prosser Creek........	Hobart Mills, Cal.........	48	518	924	5	27	24
Little Truckee.......	Starr, Cal...................	166	1 370	1 809	4	20	23
Independence Creek..	Independence Lake, Cal..	8.5	230	286	5	33	42
Carson (East Fork)..	Gardnerville, Nev.........	361	2 400	3 430 3 162	8	18 20	22
Carson................	Empire, Nev...............	988	2 561	4 000 3 791	9	9.2 10.3	10.3
Carson (West Fork)..	Woodward, Cal...........	70	900	1 570 1 450	12	28 31	30
Carson (East Fork)..	Rodenbohs, Nev..........	414	3 700	5 540	4	30	29
Susan................	Susanville, Cal....	256	1 300	1 800	4	14.5	15
Silvies................	Burns, Ore................	865	2 260	4 730	5	13.6	10
Chewaucan...........	Paisley, Ore...............	272	1 580	3 500	5	25	18
Ogden................	Ogden, Utah..............	360	1 690	3 257 2 433	11	16.0 16.2	15.2

records of both the 24-hour average rate and the maximum rate of flow will be made for our larger floods, and that for all records of floods it will be clearly stated as to which rate it refers. In this study it was difficult, in many cases, to distinguish between the two.

Acknowledgments.—As far as the writer knows, the first suggestion of the use of the element of time in a formula for flood flows was made by Allen Hazen, M. Am. Soc. C. E., in a memorandum written by him in 1910. This memorandum contained a study of maximum floods on some eastern rivers, and suggested a formula of a nature similar to the one proposed in this paper. Mr. Hazen has followed closely the progress of the study which is here presented, and to him the writer is indebted for many valuable suggestions.

The late Richard Hazen, Jun. Am. Soc. C. E., was associated with the writer in the earlier and essential portions of this study, and it was the intention that he should write the paper jointly with the writer. As this is now impossible, the writer can but acknowledge his indebtedness and pay tribute to the great amount of able work done by Mr. Richard Hazen in the preparation of this paper.

The writer also wishes to acknowledge his indebtedness to those who have furnished data for the paper. Free use has been made of

TABLE 25.—VALUES FOR COEFFICIENT, C, IN FORMULA, $Q = C\ A^{0.8}\ (1 + 0.8 \log . T)$.

SOUTHERN PACIFIC COAST.

Name of stream. (1)	Location of station. (2)	Catchment area, in square miles, A. (3)	Flood Flows, in Cubic Feet per Second. 24-Hour Average. Average yearly. Q (Ave.). (4)	Larger flood. Q. (5)	Period of observation. T. (6)	Values of C. From larger floods. (7)	From average yearly flood. (8)
Cottonwood Creek	Jamul, Cal	270	1 940	5 800	4	45	22
San Diego	San Diego (flume near Lakeside), Cal	208	1 900	3 800	4	37	27
Malibu Creek	Calabasas, Cal	97	2 560	6 800	4	117	65
Arroyo	Soledad, Cal	215	3 800	6 250	8	49	51
Mojave	Victorville, Cal	400	4 310	13 413	5	72	36
				4 820		30	
Sacramento	Jellys Ferry (near Red Bluff), Cal	9 300	129 000	254 000	15	87	86
				196 000		88	
				184 600		91	
Pitt	Bieber, Cal	2 950	13 000	27 500	5	30	22
McCloud	Gregory, Cal	608	20 000	41 000	6	149	118
Stony Creek	Fruto, Cal	601	16 200	29 300	9	100	98
				26 500		111	
Feather (North Fork)	Below Prattville, Cal	506	5 750	9 850	4	46	40
Feather	Oroville, Cal	3 640	88 100	187 000	8	154	134
Butte Creek	Butte Valley, Cal	73	1 150	1 640	4	36	37
Indian Creek	Crescent Mills, Cal	740	7 000	11 400	4	39	35
Yuba	Smartville, Cal	1 220	57 000	111 000	6	233	192
Bear	At Vantrent (above Wheatland), Cal	263	17 000	25 800	5	194	193
American	Fairoaks, Cal	1 910	55 500	105 000	5	158	130
Cache Creek	Lower Lake, Cal	500	2 300	4 340	9	17.0	15.8
				3 680		18.2	
Cache Creek	Yolo, Cal	1 230	13 500	20 100	7	40	45
Putah Creek	Winters, Cal	805	22 100	30 000	4	95	103
San Joaquin	Herndon, Cal	1 637	17 500	21 372	7	35	47
				20 780		40	
Kern	Bakersfield, Cal	2 345	4 025	9 505	20	93	80
				8 851		102	
				5 384		96	
Tule	Portersville, Cal	266	3 100	5 430	8	36	35
Kaweah	Threerivers, Cal	520	4 560	9 210	6	38	30
Kings	Sanger, Cal	1 740	19 000	43 930	14	58	49
				26 609		54	
Merced	Above Merced Falls, Cal	1 090	13 000	27 500	8	59	48
Tuolumne	La Grange, Cal	1 500	18 900	52 000	15	76	54
				24 400		64	
				21 800		60	
Stanislaus	Oakdale, Cal	1 051	9 700	13 940	5	34	37
Stanislaus	Knights Ferry, Cal	935	25 000	57 200	6	150	106
Mokelumne	Clements, Cal	642	8 530	15 300	5	55	49

many papers and reports. Records of great value, owing to their completeness and reliability, have been furnished by John H. Cook, M. Am. Soc. C. E., for the Passaic River; by Richard A. Hale, M. Am. Soc. C. E., for the Merrimac River; and by James L. Tighe, M. Am. Soc. C. E., for the Fomer River.

TABLE 26.—VALUES FOR COEFFICIENT, C, IN FORMULA, $Q = C\ A^{0.8}\ (1 + 0.8 \log. T)$.

NORTHERN PACIFIC COAST.

Name of stream.	Location of station.	Catchment area, in square miles, A.	FLOOD FLOWS, IN CUBIC FEET PER SECOND. 24-HOUR AVERAGE. Average yearly, Q (Ave.).	Larger flood. Q.	Period of observation. T.	VALUES OF C. From larger floods.	From average yearly flood.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Rogue	Tolo, Ore.	2 020	34 325	48 300	4	74	78
Umpqua (South Fork)	Brockway, Ore.	1 800	49 725	70 700	4	119	124
Columbia	Cascade Locks and The Dalles, Ore.	237 000	754 100	1 390 000	31	32	38
				1 133 000		29	
				1 040 000		30	
				903 000		30	
Clark Fork	Newport, Wash.	24 000	99 100	155 000	7	29	31
Missoula	Missoula, Mont.	5 960	20 544	35 800	7	20.0	19
Bitterroot	Grantsdale, Mont.	1 550	9 487	12 875	6	22	27
Bitterroot	Missoula, Mont.	3 260	23 070	37 437	4	39	35
Spokane	Spokane, Wash.	4 000	23 550	35 200	18	23	31
				32 875		25	
				31 500		27	
				29 024		27	
Salmon Creek	Malott, Wash.	152	356	577	5	6.7	6.5
Methow	Pateros, Wash.	1 710	11 307	11 960	6	19	29
Chelan	Chelan, Wash.	950	8 540	9 800	6	25	35
Wenachee	Cashmere, Wash.	1 250	16 450	19 000	4	43	55
Yakima	Martin, Wash.	56	2 640	6 150	6	151	105
Yakima	Cle Elum, Wash.	500	15 310	25 600	4	119	105
Yakima	Umtanum, Wash.	1 540	25 000	41 000	4	78	70
Yakima	Union Gap (near Yakima, Wash.)	3 300	29 280	63 900	7	58	45
Kachess Lake, on Kachess River	Easton, Wash.	63	1 530	2 300	4	56	55
Clealum Lake	Roslyn, Wash.	205	7 500	17 700	6	154	106
Naches	Nile, Wash.	63.6	8 412	21 100	6	74	48
Naches	North Yakima, Wash.	1 120	11 948	21 900	7	47	44
Snake (South Fork)	Moran, Wyo.	820	9 146	20 890	7	58	43
Snake (South Fork)	Lyon, Idaho	5 480	38 457	51 450	7	31	34
Snake (South Fork)	Near Minidoka, Idaho.	17 900	28 835	38 000	7	9.0	11.4
Snake (South Fork)	At Minidoka, Idaho	22 600	41 540	53 100	4	11.8	13.7
Snake (North Fork)	Ora, Idaho	1 040	3 800	5 370	7	12.2	14.6
Fall	Fremont, Idaho	390	2 984	4 160	5	23	25
Teton	Near St. Anthony, Idaho	960	4 390	7 620	7	18.4	18
Blackfoot	Presto, Idaho	1 020	1 870	2 370	5	6.0	7.3
Boise	Highland, Idaho	2 610	11 716	17 000	5	20	22
Boise	Boise, Idaho	2 450	17 880	40 130	9	44	34
				28 572		43	
Malheur	Vale, Ore.	4 190	7 893	14 540	5	11.8	10
Malheur	Near Vale, Ore.	9 900	3 571	4 445	4	1.9	2.2
Payette	Horse Shoe Bend, Idaho	2 240	14 237	19 500	4	27	29
Weiser	Weiser, Idaho	1 670	9 732	17 940	12	26	26
				17 115		28	
Grande Ronde	Hilgard, Ore.	660	3 225	4 607	4	17.3	18
Grande Ronde	Elgin, Ore.	1 350	5 696	8 349	5	16.8	18
Wallowa	Joseph, Ore.	47	659	728	4	22	30
Palouse	Hooper, Wash.	2 210	6 526	17 200	9	21	13.7
				16 430		23	
Owyhee	Owyhee, Ore.	11 100	12 250	20 920	9	6.9	7.1
				18 000		7.4	

TABLE 26.—(*Continued.*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Umatilla	Gibbon, Ore.	353	3 808	10 000 4 217	10	52 42	35
Umatilla	Yoakum, Ore.	1 200	9 200	23 900	6	51	32
John Day	McDonald, Ore.	7 800	13 070	22 800	5	11.1	10
Deschutes	Allen Ranch (near Lava), Ore.	880	1 320	2 150	4	6.4	6
Deschutes	At West's Ranch (near Lava), Ore.	1 240	2 500	4 000	4	9.2	8.5
Deschutes	Biggs, Ore.	9 180	18 050	30 600	4	14.3	12
Willamette (Middle Fork)	Jasper, Ore.	1 450	62 850	122 000	4	244	186
Willamette	Albany, Ore.	4 860	115 500	188 000 182 000 179 000 168 000	19	102 122 126 130	130
Willamette (Coast Fork)	Goshen, Ore.	690	20 500	31 300	4	109 113	109
McKenzie	Springfield, Ore.	960	27 475	37 900	4	106	113
Yamhill	Sheridan, Ore.	290	15 475	18 100	4	133	165
Cedar	Ravensdale, Wash.	170	4 612	10 800 6 420	10	98 91	76

From the report of Emil Kuichling, M. Am. Soc. C. E., on the Water Supply for the New York State Barge Canal, many data, for both American and foreign streams, have been taken, as well as a summary of the formulas previously proposed.

TABLE 27.—MISCELLANEOUS MAXIMUM FLOODS, ARRANGED IN ORDER OF VALUES OF K.

$$K = \frac{Q\ (\text{Max.})}{A^{0.8}\ (1 + 2\ A^{-0.3})}.$$

Stream. (1)	Area. (2)	Date. (3)	Flood. (4)	$1 + 2A^{-0.3}$ (5)	$A^{0.8}$ (6)	K (7)
Dry Run, Ohio	9.8	1912	4 500	1.98	5.3	360
Westfield, Mass	356.0	1878	53 000	1.34	110.0	358
Esopus, at Saugerties, N. Y	417.0	......	55 000	1.32	125.0	333
Burgoons Run, Pa	8.0	1889	3 200	2.07	5.28	292
Lake Roland, Md	39.0	1868	9 000	1.67	18.7	288
Br. Conemaugh, at Johnstown, Pa. (Johnstown flood)	48.6	1889	10 000	1.63	22.4	275
Sawkill, N. Y., 45 miles above mouth	35.0	1895	8 000	1.69	17.2	275
Chemung, at Elmira, N. Y	2 055.0	1889	138 000	1.20	446	257
Neshaminy, below Forks, Pa	139.0	......	19 000	1.45	52	252
Little Tennessee, at Judson, Tenn	675.0	......	57 500	1.28	184	245
Six Mile Creek, at Ithaca, N. Y	46.0	1905	8 500	1.63	21.4	243
Potomac, at Great Falls, Md	11 500.0	1889	470 000	1.12	1 750	240
East Branch, Delaware	920.0	1904	72 000	1.26	238	240
Tohickon, at Pt. Pleasant, Pa	102.0	......	14 100	1.50	40.5	232
Tennessee, at Chattanooga, Tenn	21 418.0	1867	735 000	1.10	2 910	228
Savannah, at Augusta, Ga	7 300.0	......	310 000	1.14	1 230	221
Perkiomen, at Frederick, Pa	152.0	......	17 600	1.44	56	217
Spring Creek, Pa	11.6	1908	3 000	1.96	7.10	216
Croton, at Croton Dam, N. Y	339.0	1867	30 000	1.35	105.0	212
Catskill, at Woodstock, N. Y	210.0	1901	21 000	1.40	72	208
Susquehanna, at Harrisburg, Pa	24 030.0	1889	700 000	1.10	3 200	200
Ramapo, N. J	118.0	1903	12 500	1.49	42.3	198
Rock Creek, D. C	77.5	......	9 800	1.54	32.7	195
Gunpowder, Md	302.0	1889	25 000	1.36	96.4	191
Millbrook, N. Y	9.4	1905	2 300	2.02	6.10	191
Delaware, at Stockton, N. J	6 855.0	1841	255 000	1.14	1 170	190
Monongahela, Pa	5 430	1888	207 000	1.15	975	184
Nine Mile Ck., at Stittville, N. Y	62.6	......	7 820	1.58	27.5	180
Raritan, at Bound Brook, N. J	879	1882	52 000	1.26	230	180
Nashua, Mass	109.0	1848	11 400	1.49	42.8	179
Stony Creek, at Johnstown, Pa	428	......	30 000	1.32	127	179
Youghiogheny, Pa	782.0	1888	46 000	1.27	206	177
Flat River, R. I	61.0	1843	7 350	1.58	26.5	176
Susquehanna, at McCalls Ferry	26 766.0	1904	671 000	1.09	3 500	176
Trout Brook, at Brooksport, N. Y	25.0	......	3 950	1.76	13.1	171
Pequonnock, Conn	25	......	4 000	1.76	13.2	171
Kennebec, Me	4 270	1901	156 800	1.16	802	168
Schoharie, N. Y	930	1901	49 600	1.26	236	167
Tuckaseegee, at Bryson, N. C	662	......	38 750	1.28	180	163
Mad Brook, N. Y	5	1905	1 300	2.23	3.62	161
Susquehanna, at Danville, Pa	11 070	1902	305 000	1.12	1 720	159
Fomer, above reservoir, Mass	13	......	2 380	1.92	7.8	159
Buffalo Creek, N. Y	420	1902	23 000	1.32	125	152
Ohio, Pa	19 000	1907	440 000	1.10	2 650	151
Rhine, at Macon, Ga	2 574	......	96 500	1.19	535	151

TABLE 28.

Catchment area, in square miles. (1)	FLOW FROM FORMULA: $Q\ (\text{Max.}) = C\ A^{0.8}\ (1 + 0.8 \log. T)\ (1 + 2\ A^{-0.3})$ $C = 65$, $T = 20$; A in square miles. (2)	FLOW BY MCMATH FORMULA: $Q = C\ R\ \sqrt[5]{S\ A^4}$ $C = 0.50$; $R = 2.75$ in.; A in acres. (3)
0.1	104	76 ($S = 30$)
1.0	398	440 ($S = 20$)
10.0	1 680	2 420 ($S = 10$)

TABLE 29.—(*Continued.*)

15.....	Possenti............	$Q = C_2 \frac{R_2}{L_1}\left(A_2 + \frac{A_1}{3}\right)$	L = length of water-shed. Assume for C_2 = 1 010 (Kuichling), R_2 = 6 in. rain in 24 hours, $L_1 = \sqrt{2A}$ as in (12), $A_2 = \frac{A}{2}$ Hilly part of water-shed, $A_1 = \frac{A}{2}$ Level part of water-shed. Formula reduced to $Q = 2\,856\, A^{\frac{1}{2}}$.
16.....	Cramer.............	$Q = \frac{C_3 R_3\, m\, A\, (S_2)^{\frac{1}{3}}}{9 + (0.0658\, m\, R_3\, A)^{\frac{1}{3}}}$	Reduced by Kuichling, for conditions on Mohawk River, to $Q = \frac{80.6}{1 + 0.1\,347\,(A)^{\frac{1}{3}}}\, A$
17.....	Lauterburg.........	$Q = A\left[\frac{615}{6 + 0.00259\, A} + 0.53\right]$	
	Kuichling...........	$Q = \left(\frac{44\,000}{A + 170} + 20\right) A$...........	(1) for flood exceeded occasionally.
		$Q = \left(\frac{127\,000}{A + 370} + 7.4\right) A$..........	(2) for flood exceeded rarely.
	E. C. Murphy and others...........	$Q = \left[\frac{46\,790}{A + 320} + 15\right] A$...........	Formula taken from U. S. Geological Survey, Water Supply and Irrigation Paper No. 147.

TABLE 29.—Formulas Which Have Been Proposed for Use in Obtaining the Maximum Flood Flow.

The following formulas are taken from the Report on the Barge Canal, State of New York, 1901. Part 14 of the Report on Water Supply by Emil Kuichling, pp. 844 to 851.

No. (1)	Author of formula. (2)	Formula. (3)	Notes. (4)
1	Fanning	$Q = 200\ A^{\frac{5}{6}}$	Adapted to rivers in New England, etc. A = catchment area, in square miles.
4	Dickens	$Q = 500\ A^{\frac{3}{4}}$	Adapted to rivers in Central Provinces, India. This formula is also given with the following coefficients: 200, 825, 1 200, and 2 200; each one is applicable to a different part of India; 500 is here taken as a representative value.
8	Ganguillet	$Q = \dfrac{1\,421\ A}{3.11 + \sqrt{A}}$	Adapted to Swiss streams.
9	Italian	$Q = \dfrac{1\,819\ A}{0.311 + \sqrt{A}}$	Adapted to streams in Northern Italy.
10	Italian	$Q = \dfrac{2\,600\ A}{0.311 + \sqrt{A}}$	Adapted to small brooks in Northern Italy.
11	O'Connell	$Q = \sqrt{458\ (640\ A + 4.58)} - 45.8$	Adapted to small districts.
12	Dredge or Burge	$Q = 1\,300\ \dfrac{A}{L^{\frac{2}{3}}}$	If A is taken as a rectangle having dimensions L and $\frac{L}{2}$, $A = \frac{L^2}{2}$, and the formula reduces to $Q = 1\,030\ A^{\frac{2}{3}}$.
13	Craig	$Q = 440\ n\ B$ hyp. log. $\dfrac{8\ L^2}{B}$	n = coefficient for the drainage basin, assumed as 1.16; L = extreme length of drainage basin; B = average width of drainage basin. If L is taken as being equal to $2\ B$, the formula reduces to $Q = 365\ \sqrt{A}$ hyp. log. $(22.7\ \sqrt{A})$.
14	Bürkli-Ziegler	$Q = C_1\ R_1 \left(\dfrac{S_1}{A}\right)^{\frac{1}{4}} A$	Assume for $C_1 = 70$ $R_1 = 3$ in. of rain per hour. $S_1 = 4$ (slope per 1 000) Formula reduces to $Q = 296\ A^{\frac{3}{4}}$.

TABLE 30.—FLOOD FLOWS ON FOREIGN STREAMS.

(Data from Report on Barge Canal, State of New York, Part 14, by Emil Kuichling.)

$$K = \frac{Q}{(A^{0.8})\ (1 + 2\ A^{-0.3})}.$$

River. (1)	Area. (2)	Date. (3)	Flood. (4)	$1 + 2A^{-0.3}$ (5)	$A^{0.8}$ (6)	K (7)
Pliessnitz, Germany	58.0	1890	47 700	1.59	25.5	1 180
Irrity, India	336	....	150 000	1.34	104	1 070
Towbrapoorny, India	587	....	190 000	1.29	165	890
Dept. de l'Ardeche, France	938	1827	247 000	1.25	239	827
Zacken, Germany	42.5	....	21 000	1.65	20.0	635
Kemlitz and Dittelsdorfwasser, Germany	7.4	1887	6 790	2.11	5.1	630
Spree, Germany	6.7	1887	6 210	2.12	4.70	620
Wittgendorfbach, Germany	3.6	1887	3 650	2.37	2.80	550
Landwasser, Germany	6.1	1887	5 050	2.16	4.30	540
Kemlitz, Germany	5.4	....	4 500	2.20	3.90	515
Dittelsdorfwasser, Germany	2.0	1887	2 287	2.61	1.76	495
Landwasser, Germany	3.8	1887	3 400	2.35	2.95	490
Queis, Germany	116.0	1888	30 700	1.48	45.0	460
Tessin, Bellinzona, Italy	541	....	89 000	1.30	154	444
Loire, France	2 200	1846	248 000	1.20	475	435
Wittgendorfbach, Germany	1.3	1887	1 450	2.8	1.25	415
Bruna, Italy	189	....	35 700	1.41	67.0	375
Landwasser, Germany	20.1	1887	7 350	1.81	11.0	370
Stream in Switzerland	87.5	....	18 500	1.52	35.0	350
Nebenwasser, Germany	7.2	1887	3 550	2.11	4.90	340
Queis, Germany	183.5	1888	30 200	1.41	65.0	330
Allaciente, Italy	32.4	....	8 350	1.70	16.0	305
Hungary	7.7	1875	3 170	2.09	5.20	290
Mandau, Germany	50.2	1887	10 500	1.61	23.0	285
Rhine, Germany	1 620	....	121 000	1.22	370	268
Brook near Dublin, Ireland	10.84	1891	3 560	1.98	6.8	260
Woodhead Reservoir, England	11.0	1849	3 520	1.98	6.9	260
Mandau, Germany	119	1890	16 000	1.48	46.0	235
Ostrawitza, Germany	313	1894	34 000	1.35	99	254
Murg, Germany	184	....	22 900	1.41	65	250
Kinzig, Germany	386	....	38 800	1.33	117.0	250
Loire, France	6 945	....	318 500	1.14	1 185	240
Schopsbach, Germany	3.3	1887	1 500	2.40	2.65	235
Murg, Germany	246	....	24 700	1.38	80	224
Wittig, Germany	122	1880	14 800	1.47	47	214
Kinzig, Germany	550	....	42 200	1.30	156	208
Wiese, Germany	163	....	17 600	1.43	59	208
Töss, Germany	63	1876	8 500	1.57	27	200
Olsa, Germany	435	....	33 700	1.32	128	198
Iller, Germany	367	....	27 200	1.34	112	179
Elz, Germany	185	....	15 900	1.41	65	172
Torside and Rhodeswood Reservoir, England	24.1	1852	3 860	1.77	12.8	170
Serein, France	226	....	17 700	1.39	77.0	165
Serein, France	108.3	....	10 600	1.49	43.0	165
Olsa, Germany	291	....	20 800	1.36	94	163
Brenne, France	145	1874	12 400	1.45	54	159
Cure, France	208	....	15 900	1.40	72	159
Lausitzer, Germany	481	1880	29 000	1.31	140	158
Neckar, Germany	4 770	....	159 000	1.16	875	157
Ombrone, Italy	1 620	....	69 500	1.22	370	154
Medlock, England	18.8	1857	3 030	1.83	10.6	156

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PAPERS AND DISCUSSIONS

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A MECHANISM FOR METERING AND RECORDING THE FLOW OF FLUIDS THROUGH VENTURI TUBES, ORIFICES, OR CONDUITS BY INTEGRATING THE VELOCITY HEAD.*

By J. W. Ledoux, M. Am. Soc. C. E.

During the last century, and even prior thereto, investigations, both theoretical and practical, and many experiments were made in order to solve the problem of the flow of water through pipes, orifices, short tubes, etc. Venturi, an Italian investigator, made very interesting experiments about 1790, and devised what has since been called Venturi's tube, which, due to its peculiar shape, possessed the property of discharging water with a very small amount of friction. He, as well as later investigators, deduced formulas for the velocity and velocity head which do not differ much from those at present in use.

In 1887 and 1888 Clemens Herschel, M. Am. Soc. C. E., first suggested the practical use of Venturi's tube as a water meter.† His suggestion was far-reaching, because any device that could be used to record or integrate the velocity head of the Venturi tube would also perform that function for any orifice or contraction in a pipe or conduit wherein the flow is a function of the velocity head. Since that time many efforts have been made, with varying degrees of success, to design a registering mechanism which would indicate reliably the

*This paper will not be presented at any meeting, but written communications on the subject are invited for publication with it in *Transactions*.

† *Transactions*, Am. Soc. C. E., Vol. XVII, p. 228, and Vol. XVIII, p. 133.

total discharge through such a tube or orifice. Mr. Herschel has made several inventions of this character.

One of the most attractive devices for this purpose consists of a small meter in a by-pass connecting the full and contracted sections of a Venturi tube. Several engineers, including the writer, have independently conceived this idea, but afterward abandoned it as impracticable. At high velocities such a contrivance will give approximate results, but when the velocity is low, the velocity head, or moving force—which varies as the square of the velocity—is too minute to operate a moving mechanism.

Some of the early devices for indicating and recording the velocity head were based on Bourdon tubes, and in some cases diaphragms balanced by springs were used. One of Mr. Herschel's earliest devices was an ingenious apparatus based on the former principle; but, eventually, all these were abandoned in favor of mercury, which was found to be much more constant, reliable, and satisfactory as a transmitting medium.

The fundamental principles of the subject will be considered briefly. The flow of water and other liquids as well as gases follows the eternal and unchangeable law of gravity. For steady flow this may be represented by the expression: "Velocity is proportional to the square root of the head producing velocity," or, algebraically,

$$V = C \sqrt{H},$$

in which $V =$ the velocity, in any convenient unit,

$H =$ the head producing such velocity,

and $C =$ a constant depending on the unit of measurement and the character of space through which the fluid flows.

V may be expressed in feet per second, miles per hour, etc., and H, the effective head, may be expressed in feet, or in pounds per square inch, etc.

The space may be a pipe of any length, a submerged orifice, an open inclined channel, a Venturi tube, or a nozzle. It is seen that this is the form of the simplest equation of a parabola:

$$y^2 = cx.$$

For practical purposes, the ideal form of meter would be a device, connected by small tubes with adjacent parts of a pipe through which fluid is flowing, which would measure automatically the square root

of the head or pressure producing the velocity. Such a device would offer no resistance or obstruction to the flow through the pipe. It has been impossible, heretofore, to achieve this ideal, because the forces due to velocity head are so minute as to be difficult, if not impossible, to measure or integrate when the velocity is low.

Theoretically, the Venturi tube is a contraction in the pipe, formed so as to cause small frictional resistance to flow; and it is remarkable how slight this contraction may be in order to produce the same difference in velocity head as that caused by Pitot tubes without contraction in the pipe. In fact, the diameter of the contracted portion need not differ from that of the full section by more than 17.7% in order to produce the full effect of two Pitot tubes, one pointing up and one pointing down stream, with their openings in the center of the pipe, or at the points of maximum velocity. In practice, however, the Venturi tube is composed of a short pipe continuously connected with the main pipe by a conical section pointing up stream and a longer conical section pointing down stream, the convergence of these two sections being dependent on experimental determinations, the object being to obtain the highest flow with the least frictional or unrecoverable loss of head through the entire Venturi tube. These angles of convergence and divergence have been determined by Venturi and, in more modern times, by Weisbach, Eytelwein, Francis, Smith, Herschel, and possibly others, but, at any rate, it is pretty well settled that they should be somewhere between fairly wide limits, beyond which the results are certainly not as good. However, they may be relatively the same for all Venturi tubes, whether the contraction is nearly as large as the pipe or very much smaller, the difference being that in the former case the entire Venturi tube would be short and in the latter case long. Of course, the purpose of a Venturi tube, the contracted section of which is small as compared to the full bore of the pipe, is to exaggerate the velocity head indications so that they can be observed and measured, especially for low flows. To illustrate, consider the simple formula of a standard Venturi tube, having a coefficient of velocity = 0.977:

$$V = 7.84 \left(\frac{H}{\left(\frac{D}{d}\right)^4 - 1} \right)^{\frac{1}{2}}$$

in which the only two variables are V and H.

V = the velocity through the full section, in feet per second;
H = the difference in piezometric heads between the up-stream section and the contracted section, in feet;
D = the diameter (or radius) of the full section;
d = the diameter (or radius) of the contracted section.

This formula may be written:

$$H = 0.0163\, V \left(\left(\frac{D}{d} \right)^4 - 1 \right).$$

Now, assume a velocity in the main as low as 0.25 ft. per sec. Then the formula may be written

$$\left(\frac{D}{d} \right)^4 = 1 + 982\, H;$$

and assume 0.01 ft. to be as low as it is possible to indicate H; then

$$\frac{D}{d} = \sqrt[4]{10.82} = 1.86,$$

which means that when the velocity through the main is as low as 0.25 ft. per sec., if it is desired to get an indication of the velocity head as great as 0.01 ft., the contracted section of the Venturi tube must be less than 54% as large in diameter as the main. However, with a tube having ratios of diameters equal to 3 to 1,

$$H = 0.0815 \text{ ft. for } V = 0.25 \text{ ft. per sec.}$$

Even this result cannot be obtained with the best apparatus formerly in use, unless one of the essential features of the Venturi meter is seriously sacrificed, namely, the measurement of high velocities.

The best types of Venturi meter registers have formerly depended for their registration on some form of cam having a parabolic curve, fashioned around a drum or revolving about a center. Near zero, or the origin, the curve changes in direction rapidly, and at zero crosses one of the axes of reference at right angles and becomes parallel to the other. It is probably this feature, more than any other, which has limited the minimum velocity measurable by a Venturi meter; and though the measurement of low velocities is attainable by a high ratio of tube diameters, there is thus encountered the other difficulty of excessive frictional loss through the Venturi tube for comparatively high velocities. If it is even intended to measure velocities as high

as 10 ft. per sec., which is occasionally desirable, the frictional head through a Venturi tube having a ratio of 3 to 1 in diameters, or 9 to 1 in areas, would be 17 ft., obtainable from the formula:

$$H_f = 0.0021 \ V^2_2,$$

in which H_f = the frictional head, in feet,

and V_2 = the velocity through throat, in feet per second.

Besides that, in any form of register depending on mercury as the medium of indicating the velocity head, in order to cover ranges of velocity from 10 ft. per sec. down to zero, the apparatus would have to be more than 11 ft. high. In a tube having a ratio of 2 to 1 in diameters, or 4 to 1 in areas, with a velocity of 10 ft. per sec. through the main, the frictional head would be only 3.36 ft. This is still a material loss, but a velocity of 10 ft. per sec. is unusually high.

It must be remembered that, as far as metering a fluid is concerned, any form of orifice or contraction in a pipe would be just as good as a Venturi tube. It is also highly probable that the coefficient of flow would remain as nearly constant through just as wide a range of velocities; but the great advantage of a Venturi tube is in its small frictional resistance to flowing fluid, and in this respect it is the best shape yet devised.

The writer will now describe a form of meter register particularly adaptable to the registration of flows through any form of orifice, such as by the use of Pitot tubes and Venturi tubes of small ratios and consequently minimum frictional heads. The fundamental principles were discovered by the writer in 1904 and were finally developed into the best practical working form in 1909. The basic idea is a float, shaped so that, when acted on by the head due to the velocity of flowing liquid, its movement will be directly proportional to that velocity.

The device is novel in form, and covers a principle in hydraulics, which, although rational and perfectly obvious on analysis, the writer believes has not heretofore been recognized. This may be stated as follows: If a hollow body of any shape, with open bottom, floats freely in a liquid having the same specific gravity and touches another liquid of greater specific gravity, and if the relative pressures without and within this hollow body are changed so as to make the internal pressure less than the external pressure, then the body will sink into the heavy liquid, and the amount of displacement will be exactly

equal to the quantity of the heavier liquid which will pass up into the interior of the body and above the level of the heavier liquid outside of the body.

Let the hollow body, or float, be represented by *n n a a*, Fig. 1; assume it to be a figure of revolution, and call the total volume of heavy liquid, *a a m m*, within the float M.

The principle may be understood by a consideration of the laws of equilibrium—the algebraic sum of the vertical forces must be equal to zero; the sum of the horizontal forces, and the sum of the moments must all be equal to zero. We need consider only the first condition as affecting the problem. At the plane, *b c c b*, the heavier liquid is subject to the same unit pressure within and without the hollow body, but the resultant of external forces acting downward on the hollow body is measured by the weight of the heavier liquid, *m m c c*, and the total upward force acting on the body is the displacement of the annular portion of the body, *bca-bca*. For equilibrium, the algebraic sum of these two forces must be equal to zero, and, as one is positive and the other negative, they must be equal in amount; but, if that is the case, the entire quantity of liquid equivalent to the displacement of the hollow body, and no more, must be found in the interior of the hollow body, and hence the outer level of the surface of the heavy liquid does not change with variations of pressure outside and

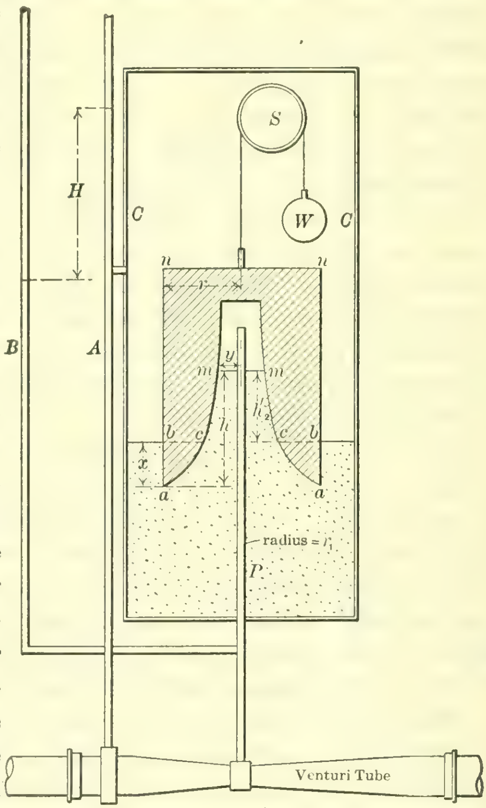

FIG. 1.

inside the float.* If there is a difference of pressure, H, then the float will sink into the heavier liquid an amount represented by the annular volume, *acb*, which will be called V; and the net volume of liquid $m\ m\ c\ c$, will also be equal to V, and h_2 will be proportional to H. As before stated, the level bb, will always be the same, no matter what the values of H, h_2, and V may be.

Let x = the vertical movement of the float from a given datum;
H = the Venturi head;
h_2 = the corresponding mercury head;
v = the velocity through the Venturi tube;
y = the ordinate or variable radius of the inner portion of the float;
h = the corresponding abscissas, measured from the bottom of the float;
r = the constant radius of the outer cylindrical portion of the float;
M = the total volume, $a\ a\ m\ m$, of the heavy liquid within the float;
V_0 = the volume of heavy liquid above cc;
and V_1 = the volume of the float below $bc\ cb$.

Assume the radius of the pipe, P, to be small and negligible.

Take, by hypothesis, $v \propto x$, also for unity the coefficient, $x^2 = h_2$, for $v \propto \sqrt{H} \propto \sqrt{h_2}$.

Therefore, the cross-section of the float must conform to the following equation:

$$y^2 = \frac{r^2}{2\sqrt{h + \frac{1}{4}}}$$

derived as follows:

$$H = 12.6\ h_2$$

$$h = x + h_2 = x + x^2.$$

Geometrically, $M = \pi\, r^2\, x + V_0 - V_1$

but $V_0 = V_1$, therefore, $M = \pi\, r^2\, x$ ....(6)

Differentiating, we have $\frac{dM}{dx} = \pi\, r^2$ ....(7)

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* If the float were not free to move vertically—that is, if it were restricted in any way, as with a variable lever arm, counterweight, or spring—then the movements of the liquids would not follow the law stated; but, as the difference of pressure became greater, the surface level of the heavy liquid would fall below a fixed level on the outside and rise above a fixed level on the inside.

Also, by the differential equation of cubature,

$$M = \pi \int_{h=0}^{h=x+x^2} y^2\, dh \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

Differentiating, we have $\dfrac{dM}{dx} = \pi\, y^2\,(1 + 2\,x) \ldots\ldots\ldots\ldots\ldots\ldots (9)$

Combining Equations (7) and (9) and reducing, we have

$$y^2 = \frac{r^2}{1 + 2\,x} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

$$\text{but } h = x + x^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots (11)$$

$$\text{hence } x = -\frac{1}{2} \pm \sqrt{h + \frac{1}{4}} \ldots\ldots\ldots\ldots\ldots (12)$$

and as $h = 0$ when $x = 0$, we must use the plus sign before the radical, therefore,

$$y^2 = \frac{r^2}{2\sqrt{h + \frac{1}{4}}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (13)$$

This is an equation of the fifth degree, as between the two variables, h and y. No attempt has been made to discuss this equation exhaustively or plot all the loci, for, though this would be interesting from a purely mathematical standpoint, it is evident that only that locus will satisfy the physical conditions wherein both h and y have positive, real values.

$$\text{For } h = 0,\ y = r\ ;\ \text{and for } h = \propto,\ y = 0,$$

thus it is seen that there are no values of h between 0 and $\propto$ which give infinite or imaginary values of y. As a consequence, the integrating apparatus operated by the sheave, S, is theoretically accurate from zero up to any practical limit that may be desired.

The shape of the float is such that its vertical movement is proportional to the square root of h_2 or H (the mercury and water Venturi heads, respectively); and, as the velocity through the Venturi tube is also proportional to the square root of H, the vertical movement is directly proportional to the velocity or quantity of water passing through the Venturi tube. The same principle will hold true if the Venturi tube is replaced by any form of orifice, or if the pipes, A and B, be connected with Pitot tubes in a main; for, in any of these cases, the H values represent velocity heads, the same as they do for Venturi

tubes, and the velocity heads are always proportional to the square of the velocity producing the head.

It is perfectly practical to have x less or greater than h_2, for, if we assume $cx^2 = h_2$, Equation (13) becomes:

$$y^2 = \frac{r^2}{2\sqrt{c}\sqrt{\frac{c}{4} + h}},$$

which is the more general form, in which we can give to c any value, consistent with practical limitations. For general use, however, Equation (13) is satisfactory, particularly as there is no value of c which increases or diminishes the accuracy of the apparatus.

In these calculations, the radius of the pipe, P, within the float, is assumed to be so small that it does not affect the results. Even if no correction is made for this volume, the error at low velocities would be negligible, and, at maximum velocities, it would be less than half of 1%, provided the pipe is made as small as possible. Its effect is to raise slightly the level of the heavy liquid, both inside and outside the float, by the same amount and aggregating the volume of displacement of the pipe, P; and, where it is desired to make this inside pipe, P, of an appreciably large outside diameter, allowance must be made for its disturbing influence. The final rationally derived formulas for that purpose are as follows:

$$x^2 = h_2$$

$$h = x + x^2 + \frac{r_1^2\, x^2}{y^2 + R^2 - r_1^2 - r^2}$$

$$x = \frac{(r^2 - y^2)\,(y^2 + R^2 - r_1^2 - r^2)}{2\, y^2\,(y^2 + R^2 - r_1^2 - r^2) - 2\, r_1^2\,(r^2 - y^2)}$$

in which the only variables are x and y,

h_2 = the mercury rise as before;

x = the vertical movement of the float;

and y = the variable radius of the interior.

The constants are:

R = radius of cylinder containing float;

r = radius of outer surface of float;

and r_1 = radius of pipe P.

To use these formulas practically, it is necessary to tabulate x and y, h_2, and finally h; h representing the abscissas, as before, and y the

ordinates. The necessity of this complication can be avoided by enlarging the outer cylinder at the location of the surface of the mercury.

Although the writer has devised many other forms and modifications, the form of float illustrated in Fig. 1, and covered by Equations (13) and (14), is believed to be by far the most practical, because it provides for maximum increments of volume and consequent accuracy at minimum velocities; and, with a float of a given radius, the minimum clearances are possible with the smallest cylindrical casing; also, there are several other practical advantages of importance. When this paper was first prepared it contained a discussion of every practical modification of form, with the derivation of the equation of each float. These, however, would take up too much space and be of mathematical rather than of mechanical interest.

At first thought, it might seem that a more practical shape would consist in a cylindrical interior and a curved exterior, because that would be formed more readily and accurately. Its cross-section would be a curve of the second degree, and the volume would be a paraboloid of revolution, convex outwardly. However, it cannot be made with greater accuracy, or probably with greater facility, and, for an apparatus of the same size, the form shown in Fig. 1 is almost seven times as accurate at minimum velocity.

The essential requirements of a water meter are:

1st. Accuracy within the range of the apparatus.

2d. Range, or ability to measure accurately flows in which the percentage of the maximum is a minimum.

3d. Minimum frictional resistance to flow.

4th. Reliability, or ability to perform with the greatest continuity, the minimum of attention, and the least danger of accident or damage.

5th. Long life and small repairs.

6th. Low cost.

7th. Simplicity.

8th. Accessibility—easy to examine and adjust.

9th. Minimum dimensions and weight, so as to occupy the least space.

10th. Good appearance.

The apparatus having the principles shown in Fig. 1, and described more in detail herein approximately fulfills these ten requirements.

One of the first difficulties to overcome was to prevent air from accumulating at the upper interior of the float in Fig. 1. Such an accumulation, of course, would lighten the float and therefore vitiate the results. Two check-valves opening upward are placed in the cap of the float. These are opened automatically when the velocity head reaches the maximum, and they can be opened at will, by a hand device, from the outside of the bottom of the pressure chamber, without otherwise dismantling the meter. This same device also automatically prevents the loss of mercury when the flow reaches an amount beyond the maximum capacity of the meter register, as it equalizes the pressure within and without the float.

An additional device for this purpose has been designed to prevent loss of mercury due to a sudden break of either of the pipes leading from the meter register to the Venturi tube, but these are safety devices of not unusual novelty, and, therefore, a detailed description of them is unnecessary.

Figs. 2 and 3 show applications of this meter register.

The float is made of hard rubber to conform to a metal template; but, to make sure that it is correct and will perform according to the theory on which it is designed, each float is tested in a regular working machine by applying, under pressure, piezometric heads corresponding to the velocity heads of the Venturi tube or Pitot tube with which it is to be used, and noting from a standard rate-of-flow dial the corresponding velocities, which are compared with the theoretical velocities.

For heads, H, greater than $\frac{1}{2}$ ft. the coefficient of velocity through a standard Venturi tube is so nearly constant as to secure results within 2% of the actual. However, with the apparatus above described, Venturi heads, H, of less than 0.01 ft. are readily integrated. The velocity coefficient through the Venturi tube, however, is materially different, amounting to as much as 7% at low velocities, and the instrument is modified accordingly so as to produce accurate results down to less than 0.01 ft.

The data for this modification, as well as the method of making the correction, are intended to be the subject of a later paper.

Leading up to the final development of the apparatus illustrated in Fig. 1, it will be interesting to consider two of the earlier forms. Fig. 4 shows an extremely simple apparatus, which, at first sight, would appear to be superior to the device shown in Fig. 1.

P is a piston, F is a shaped float, S is a sheave, and W is a displacement device, all within a casing. The upper portion of this casing is connected with a pipe from the full section of the Venturi tube, and the portion below the piston, P, is connected with a pipe leading to the throat of the Venturi tube. The differential pressure, or Venturi head, H, acts on the piston and forces the float, F, down into the mercury. As before, the problem is to shape the float so that its vertical movement from a fixed line of reference will be proportional to the square root of H. The displacement device, W, is such that when there is no flow in the Venturi tube and the apparatus is in equilibrium, the bottom of the float, a, will be tangent to the upper surface of the mercury. The level of the mercury, $m\ m$, will change, of course, as the float descends. The equation of the float, though rather more difficult to deduce, is as follows:

$$y^2 = e - \frac{f}{\sqrt{h + g}}$$

e, f, and g being constants depending on the size of the piston, P, the assumed movement of the float, F, with the given Venturi head, H, and the relative weights of mercury and water. The only radical difference in form between this formula and the one corresponding to Fig. 1 is in the constant, e, before the fraction. The curve, however, is still one of the fifth degree, and in this case when h becomes zero, y becomes zero, for the actual formula is:

$$y^2 = \frac{A_1}{\pi} - \frac{1}{2 \times 0.454\,\pi} \sqrt{\frac{\dfrac{(0.454\,a_1)^3}{0.434\,c\,a}}{h + \dfrac{0.454\,a_1}{4 \times 0.434\,c\,a}}}$$

in which a_1 = the area, in square inches, of the cylinder containing the mercury;

a = the area of the piston, P;

h = the depth of submergence of the float in mercury, in inches;

c = the ratio of the square root of the Venturi head to the velocity;

0.434 = the ratio of the pressure, in pounds per square inch, to the Venturi head, in feet;

0.454 = the weight per cubic inch of mercury in water.

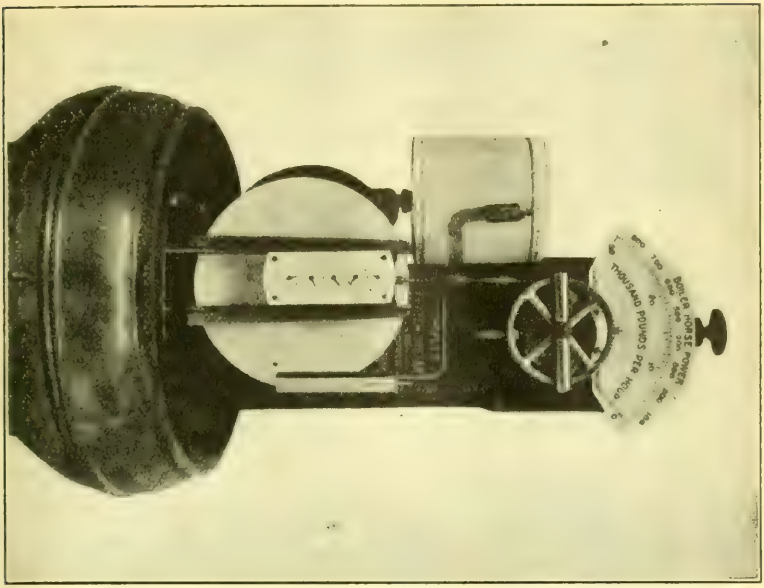
BOILER HORSE POWER
THOUSAND POUNDS PER HOUR

Fig. 2.

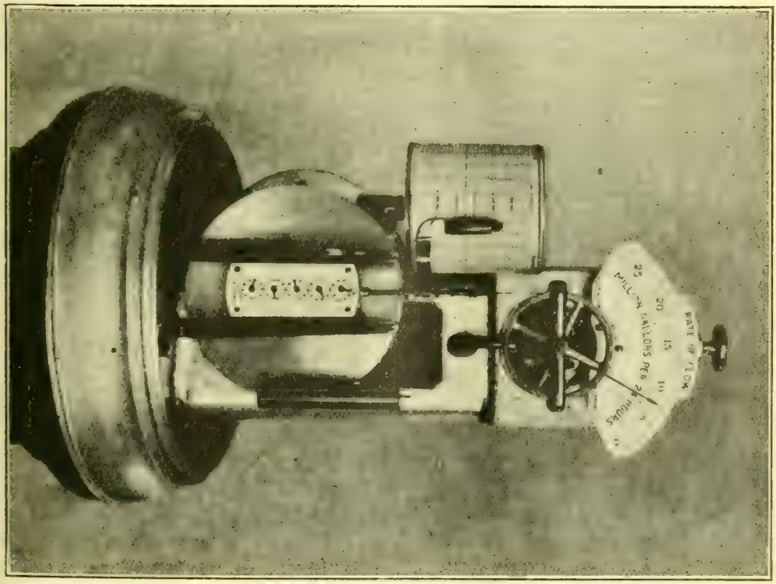
RATE OF FLOW
25
20
15

Fig. 3.

The objection to this apparatus is the friction of the piston, P. This was recognized immediately, and, to overcome it, a diaphragm of an accordion or some very flexible type was substituted for the piston; this, however, introduced difficulties caused by the elasticity of the diaphragm and the necessity of modifying the shape of the float to provide for these variations, as the diaphragm could never be depended on to remain in a permanent condition.

Another form is shown in Fig. 5. This is on an entirely different principle, but the treatment of the problem is analogous to that of Fig. 1.

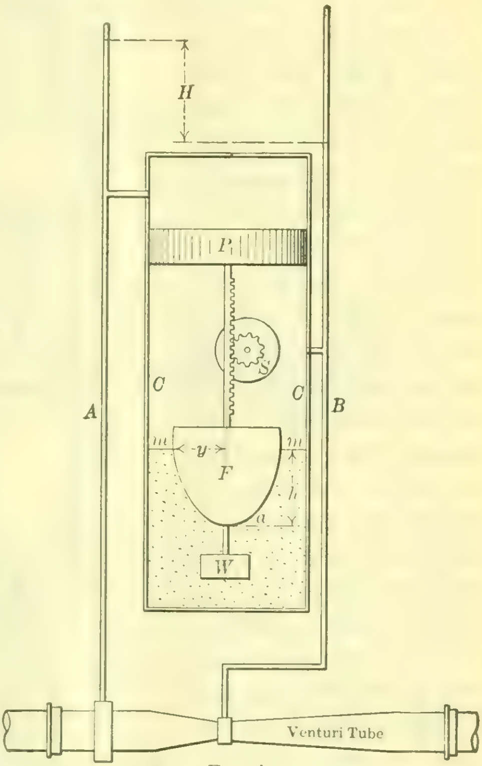

FIG. 4.

C represents a casing within which is contained a fixed displacing device, F, and a movable cylindrical vessel, P, containing, say, mercury buoyed up by the displacing volume, W. The pipe leading from the full section of the Venturi tube connects as shown above the vessel, and the pipe leading from the throat of the Venturi tube connects within the displacing device, F. The differential pressure, or Venturi head, H, forces mercury from the outside of the displacing device, F, to the inside; but, for equilibrium, the depth of the mercury in the vessel, P, must always be the same; that is, d must always be a constant. With these data it is found that the equation representing the inner curve of the displacing device is exactly the same as that of the float in Fig. 1, namely:

$$y^2 = \frac{r^2}{2\sqrt{h + \frac{1}{4}}}.$$

This device, in some respects, is superior to any of the others considered, and, in fact, it was the one of which a complete working model was first made and tested, and the results were good. The only objection is the large quantity of mercury required for the displacing device, W. It is obvious that the vertical movement of the cylindrical vessel, P, may be guided by rollers, as shown, or in some other practical manner. The cross-section of the rod, l, need not be sufficiently large to make its variable displacement affect the results appreciably.

However, the form in Fig. 1 is that which has been adopted as the most practical; and of all the twelve other devices, each of which has been developed by the writer to a working design, that shown in Fig. 5, next to that in Fig. 1, is the most meritorious. In all cases the registering mechanism outside of the casing may be exactly the same as shown. It comprises a rate-of-flow dial, a chart device to record the rate of flow, and a total-flow dial. The first requires only a graduated dial and a hand actuated by the shaft of the sheave, S. The second requires a pen reciprocating along the surface of a revolving figure having straight-line elements, such as a cylinder. The third requires a dial having hands which always revolve at a speed proportional to the angular position of the sheave, S. This is readily accomplished by hanging from the sheave, S, the dial which is connected with and operated by a traction wheel, the latter

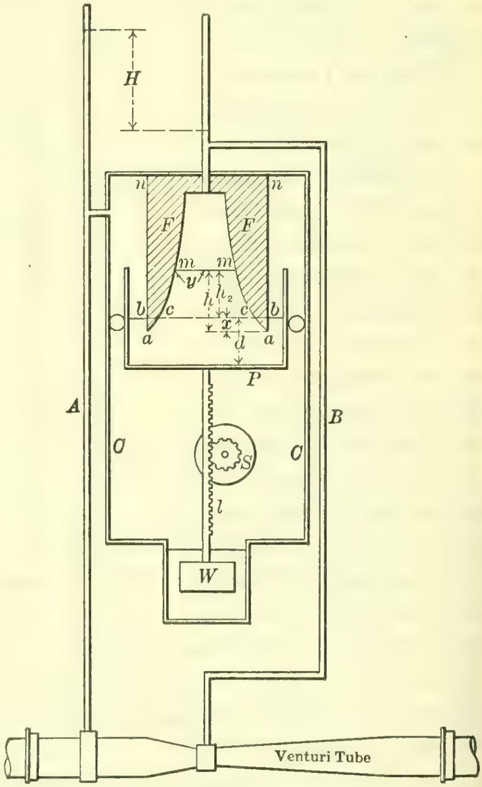

FIG. 5.

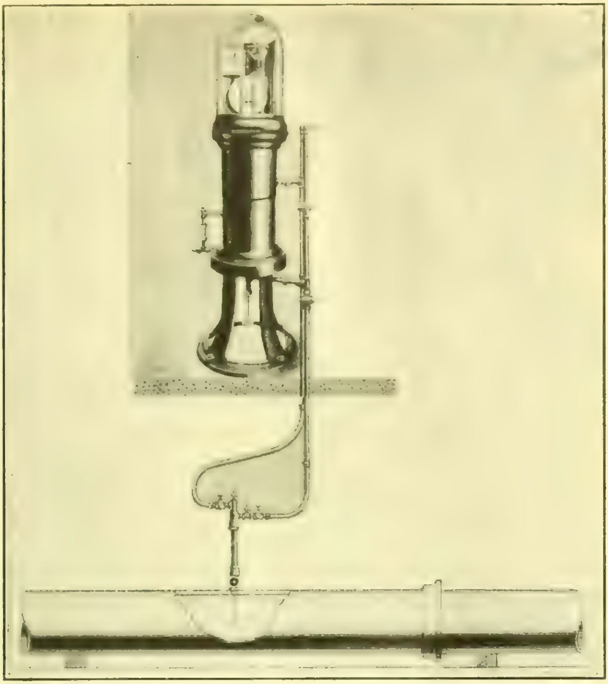

FIG. 6.—STATIONARY METER WITH PITOT TUBE.

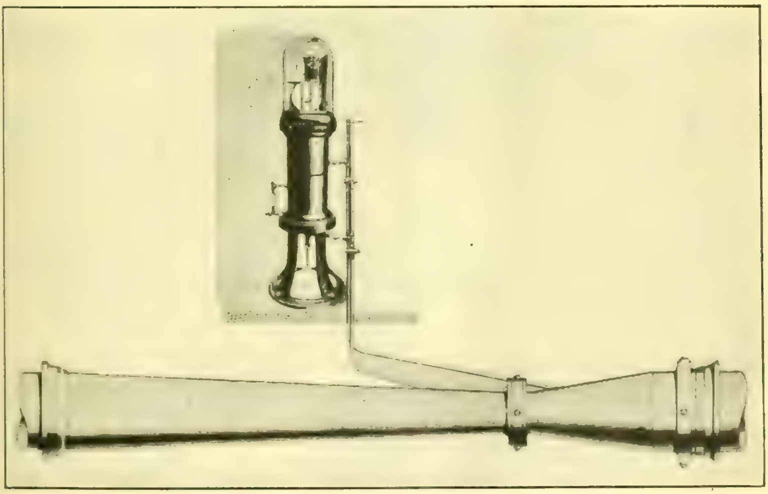

FIG. 7.—STATIONARY METER WITH VENTURI TUBE.

being rotated by a constantly revolving disk. When the sheave, S, sets at zero, the traction wheel stands at the center of the disk, and therefore has no rotating motion. As the flow increases from zero and the sheave, S, revolves, the traction wheel moves away from the center of the disk and therefore revolves at a speed proportional to its distance from the center of the disk and to the rate of flow through the Venturi tube.

There are other equally simple means of actuating the total-flow dial, but they are all on the same principle, and have been in use for several decades. The revolving flat disk is probably the oldest, but the revolving cone rivals it in antiquity. The Nicholson ship's log is a rather recent application of the latter device. It will be seen from Figs. 2 and 3 that the chart-recording cylinder and the disk are operated by the same clockwork.

Where it is intended to meter a liquid of a specific gravity different from that for which this meter is adjusted, as for instance, if the meter has been adjusted for measuring water at 50° Fahr., and it is desired to measure water having a temperature of 200° Fahr., the results can be corrected according to the following principle:

In a fluid passing through a Venturi tube or orifice, the weight is directly, and the volume is inversely, proportional to the square root of the unit weight of that fluid, for:

Letting W = the weight of the fluid,

Q = the volume of the fluid,

H = the Venturi head,

and w = the unit weight of fluid ;

then $$Q \propto \sqrt{H} \qquad (1)$$

$$H \propto \frac{1}{w} \qquad (2)$$

$$W \propto w\, Q \qquad (3)$$

Combining Equations (1) and (2), we obtain

$$Q \propto \sqrt{\frac{1}{w}} \qquad (4)$$

Combining Equations (1), (2), and (3), we obtain

$$W \propto \sqrt{w} \qquad (5)$$

Equations (4) and (5) being the stated relations.

TABLE 1.—Test of a Meter Register Based on Venturi Heads.
Float No. 46.

C	V	V_1	D	P	Date
0.010	0.195	0.194	+ 0.001	+ 0.52	August 29th, 1912.
0.013	0.226	0.225	+ 0.001	+ 0.45	
0.023	0.300	0.298	+ 0.002	+ 0.67	
0.036	0.381	0.379	+ 0.002	+ 0.53	
0.054	0.470	0.467	+ 0.003	+ 0.64	
0.078	0.571	0.562	+ 0.009	+ 1.60	
0.112	0.677	0.675	+ 0.002	+ 0.30	
0.154	0.800	0.797	+ 0.003	+ 0.38	
0.208	0.931	0.930	+ 0.001	+ 0.11	
0.279	1.079	1.080	− 0.001	− 0.09	
0.368	1.240	1.240	0.000	0.00	
0.487	1.429	1.428	0.001	0.00	
0.638	1.635	1.635	0.000	0.00	August 28th, 1912.
0.833	1.872	1.874	− 0.002	− 0.11	
1.092	2.150	2.133	+ 0.007	+ 0.33	
1.426	2.460	2.460	0.000	0.00	
1.873	2.820	2.825	− 0.005	− 0.18	
2.455	3.250	3.235	+ 0.015	+ 0.47	
3.250	3.750	3.720	+ 0.030	+ 0.81	
4.320	4.321	4.280	+ 0.041	+ 0.96	
4.830	4.570	4.540	+ 0.030	+ 0.66	
5.800	5.010	4.970	+ 0.040	+ 0.81	
7.270	5.638	5.600	+ 0.038	+ 0.68	

Tables 1 and 2 contain data relating to typical tests of meter registers constructed on the principle described herein, in which

C = the Venturi head as measured, in feet;

V = the theoretical velocity through the full section of the Venturi tube, in feet per second;

V_1 = the velocity as indicated by the meter register;

D = the differences;

and P = the percentage of error.

This meter register is in use in several important cases for recording and integrating the flow measured by Pitot tubes, and has also recently been adapted in portable form utilizing Pitot tubes for city main leakage survey purposes. This form is shown in Fig. 8. Quite a number of these instruments are already in service. A typical test of one of these recorders is shown in Table 3.

The first column shows the direction of movement, U being where the column is increasing and D where the column is decreasing.

C represents the Pitot tube velocity heads, in feet;

V represents the theoretical velocity as calculated for the Pitot heads;

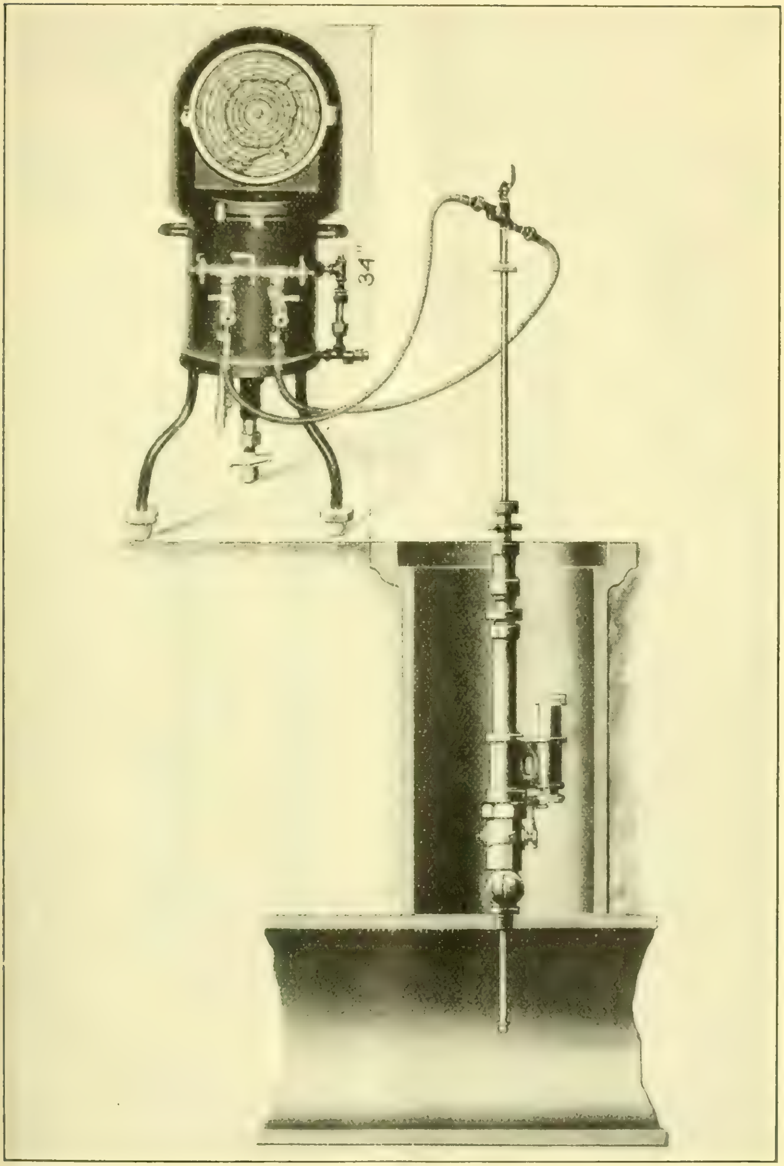

FIG. 8.—PORTABLE PITOT RECORDER. FOR MEASURING AND RECORDING FLOW OR LEAKAGE IN WATER MAINS, FLUMES, PENSTOCKS, ETC.

V_1 represents the velocity as measured by the Pitot recorder;
D represents the differences;
and P represents the percentage of error.

TABLE 2.—Test of Meter Register.

Float No. 174.

Up or down	C	V	V_1	D	P	Date
U	0.0026	0.0890	0.0960	—0.007	—7.39	December 30th, 1912.
D	0.0026	0.100	0.0960	+0.004	+4.17	
U	0.0043	0.115	0.1230	—0.008	—6.50	
U	0.0064	0.140	0.1520	—0.012	—7.89	
D	0.0064	0.145	0.1520	—0.007	—4.61	
U	0.009	0.186	0.1900	—0.004	—2.11	
U	0.013	0.218	0.220	—0.002	—0.91	
D	0.013	0.219	0.220	—0.001	—0.46	
U	0.036	0.372	0.372	0.000	0.00	
D	0.036	0.372	0.372	0.000	0.00	
U	0.054	0.458	0.457	+0.001	+0.22	
D	0.054	0.457	0.457	0.000	0.00	
U	0.111	0.658	0.660	—0.002	—0.33	
D	0.111	0.658	0.660	—0.002	—0.30	
U	0.154	0.775	0.779	—0.004	—0.51	
D	0.154	0.775	0.779	—0.004	—0.51	
U	0.208	0.910	0.910	0.000	0.00	
D	0.208	0.910	0.910	0.000	0.00	
U	0.279	1.054	1.056	—0.002	—0.19	
U	0.368	1.210	1.216	—0.006	—0.49	
D	0.368	1.210	1.216	—0.006	—0.49	
U	0.487	1.390	1.395	—0.005	—0.36	
D	0.487	1.390	1.395	—0.005	—0.36	
U	0.638	1.595	1.600	—0.005	—0.31	
D	0.638	1.595	1.600	—0.005	—0.31	
U	0.833	1.820	1.833	—0.013	—0.71	
D	0.833	1.823	1.833	—0.010	—0.55	
U	1.092	2.090	2.105	—0.015	—0.71	
D	1.092	2.087	2.105	—0.018	—0.85	
U	1.426	2.395	2.403	—0.008	—0.33	
D	1.426	2.397	2.403	—0.006	—0.25	
U	1.873	2.753	2.760	—0.007	—0.25	
D	1.873	2.752	2.760	—0.008	—0.29	
U	2.455	3.158	3.160	—0.002	—0.06	
D	2.455	3.155	3.160	—0.005	—0.16	
U	3.250	3.640	3.635	+0.005	+0.14	
D	3.250	3.637	3.635	+0.002	+0.06	
U	4.320	4.210	4.183	+0.027	+0.64	
D	4.320	4.210	4.183	+0.027	+0.64	
U	5.800	4.887	4.860	+0.027	+0.56	
D	5.800	4.895	4.860	+0.035	+0.72	
U	7.890	5.710	5.680	+0.030	+0.53	
D	7.890	5.705	5.680	+0.025	+0.44	
U	9.390	6.210	6.200	+0.010	+0.16	

TABLE 3.—Test of a Recording Register Based on this Principle and with Pitot Tube Heads.

Up or down	C	V	V_1	D	P
U	0.008	0.5	0.516	+0.016	+3.2
D	0.007	0.5	0.483	−0.017	−4.0
U	0.031	1.0	1.017	+0.017	+1.7
D	0.029	1.0	1.985	−0.015	−1.5
U	0.071	1.55	1.540	+0.040	+2.65
D	0.068	1.50	1.507	+0.007	+0.45
U	0.122	2.0	2.020	+0.02	+1.00
D	0.119	2.0	1.99	−0.01	−0.50
U	0.274	3.0	3.02	+0.02	+0.66
D	0.268	3.0	2.99	−0.01	−0.33
U	0.484	4.0	4.02	+0.02	+0.5
D	0.478	4.0	3.99	−0.01	−0.25
U	0.756	5.0	5.02	+0.02	+0.40
D	0.752	5.0	5.01	+0.01	+0.42
U	1.084	6.0	6.02	+0.02	+0.33
D	1.082	6.0	6.01	+0.01	+0.17
U	1.476	7.0	7.01	+0.01	+0.14
D	1.474	7.0	7.01	+0.01	+0.14
U	1.928	8.0	8.01	+0.01	+0.13
D	1.929	8.0	8.02	+0.02	+0.25
U	2.440	9.0	9.02	+0.02	+0.22
D	2.440	9.0	9.02	+0.02	+0.22
U	2.980	10.0	10.00	0.00	0.00
D	2.980	10.0	10.00	0.00	0.00
D	0.315	1.0	1.025	+0.025	2.5

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PAPERS AND DISCUSSIONS

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MODERN PIER CONSTRUCTION IN NEW YORK HARBOR.

By Charles W. Staniford, M. Am. Soc. C. E.

To be Presented September 3d, 1913.

Introduction.

The present general port activity and agitation for a modernization and expansion of the dock and wharfage system in New York City indicate that at last the community at large seems to realize the necessity of keeping its producing plant, the harbor, up to date and at the top notch of efficiency.

It has been said that "all roads lead to New York." Never was this more true than to-day. New York in 1913 is the world's greatest seaport, its greatest factory, and its largest department store.

There can be no question that New York City's supremacy as a manufacturing and distributing center is due to wise adaptation of its magnificent harbor. The phenomenal increase in the size of vessels, necessitating longer docks, and the great and constant increase in tonnage entering the harbor, both demand determined action in port development.

New York is approximately equidistant from the ports of Northern Europe and South America. Therefore, it will undoubtedly receive additional impetus in its commerce and shipping on the completion of

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

the Panama Canal. Further, on the completion of the New York State Barge Canal, it will have a direct all-water route to the Great Lakes and the North Middle States and Canada, and the Cape Cod Canal will tap New England commerce.

Far-sighted public men foresee that New York is destined to become the world power in commerce and industry, and realize that it must prepare for the future intelligently and on broad lines, permitting gradual expansion as required by commercial necessity.

Growth and Development of the Harbor.

In this period of harbor activity, it will be of interest to both the public and the engineer to describe the gradual development of the harbor, as such development was first systematically undertaken by the City, when, in 1870, the Department of Docks was organized for this purpose, and to show the types of pier construction evolved.

In considering the history of dock development in the City of New York, through the instrumentality of the Department of Docks, it must be borne in mind that, in its early days, the Department was greatly handicapped in its progress by the fact that the City actually owned only a very small portion of its great water-front, most of it having passed, by successive water grants, into the control of private interests.

It had been the policy of the New York State Government, prior to the organization of the Department of Docks, to give to corporate interests or private persons grants of land under water in that portion of the present City outside of Manhattan, the object and hope in making such grants being that such cession of land under water would be a sufficient incentive for the investment of private capital in the development of the port.

The hopes of the State and City were fully realized; in fact, they were so generally fulfilled that when the port authority, created by the Legislature in establishing the Department of Docks for the purpose of intelligent development under municipal control, began to consider the expansion of wharfage facilities to meet the demands of the growing commerce, it found but little actual water-front in possession or under control of the City.

That the early City authorities used wisdom and foresight in their work of providing for proper expansion of the harbor, is shown by the fact that, through their sagacity and good judgment, the number of

piers in the harbor, owned by the municipality of New York, grew from 107 in 1868, valued at $20 000 000, to 232 in 1913, valued at $100 000 000 or more.

There has accrued, therefore, to the City, a return on its investment in this development of the dock system, a large sum of money in increased valuation and annual rent receipts, the latter aggregating in round figures about $4 000 000 per annum, the interest at 4% on a capital of $100 000 000.

It will be seen that, at the outset, the Department of Docks, concluded that proper growth and expansion of the harbor under municipal control depended on the acquisition and control of water-front property; and since the organization of the Department of Docks, this has been the policy followed by the City.

When, in 1870, the municipal authorities undertook the burden of increasing the wharfage facilities of the harbor, and of procuring funds for this purpose, it became necessary, as a basis for their work, to determine on some economic form or type of construction, both in regard to the pier structure proper and also the general location with respect to the available shore front, whereby the maximum wharfage accommodation could be developed without excessive or prohibitory cost.

The limited funds available and the small extent of water-front lands under the actual control of the City called for the greatest economy in space, the land requiring intense development in order to obtain the greatest possible extent of wharfage.

Bond issues to be applied to the development of wharfage had to show the same return on the investment, when executed by the City authorities, as if these finances were handled by private parties or corporate interests. Therefore, what might be termed the "principle of economy in expenditure of land and funds" was, of necessity, followed, and this principle was generally adopted by private interests as well, the consequent intensive use of the water-front resulting in the adoption of a uniform method of development by a definite system, namely, parallel piers generally at right angles to the general direction of the water-front, with intervening slips wide enough to accommodate vessels of the type intended to berth at the piers.

This parallel system of economically constructed piers, with its resulting economy in space occupied and capital expended, was undoubtedly one of the greatest factors in stimulating the development

and expansion of the wharfage facilities in the harbor, and in keeping them abreast of the constant increase in shipping and commerce. It has also created by far the greatest wharfage space of any harbor in the world.

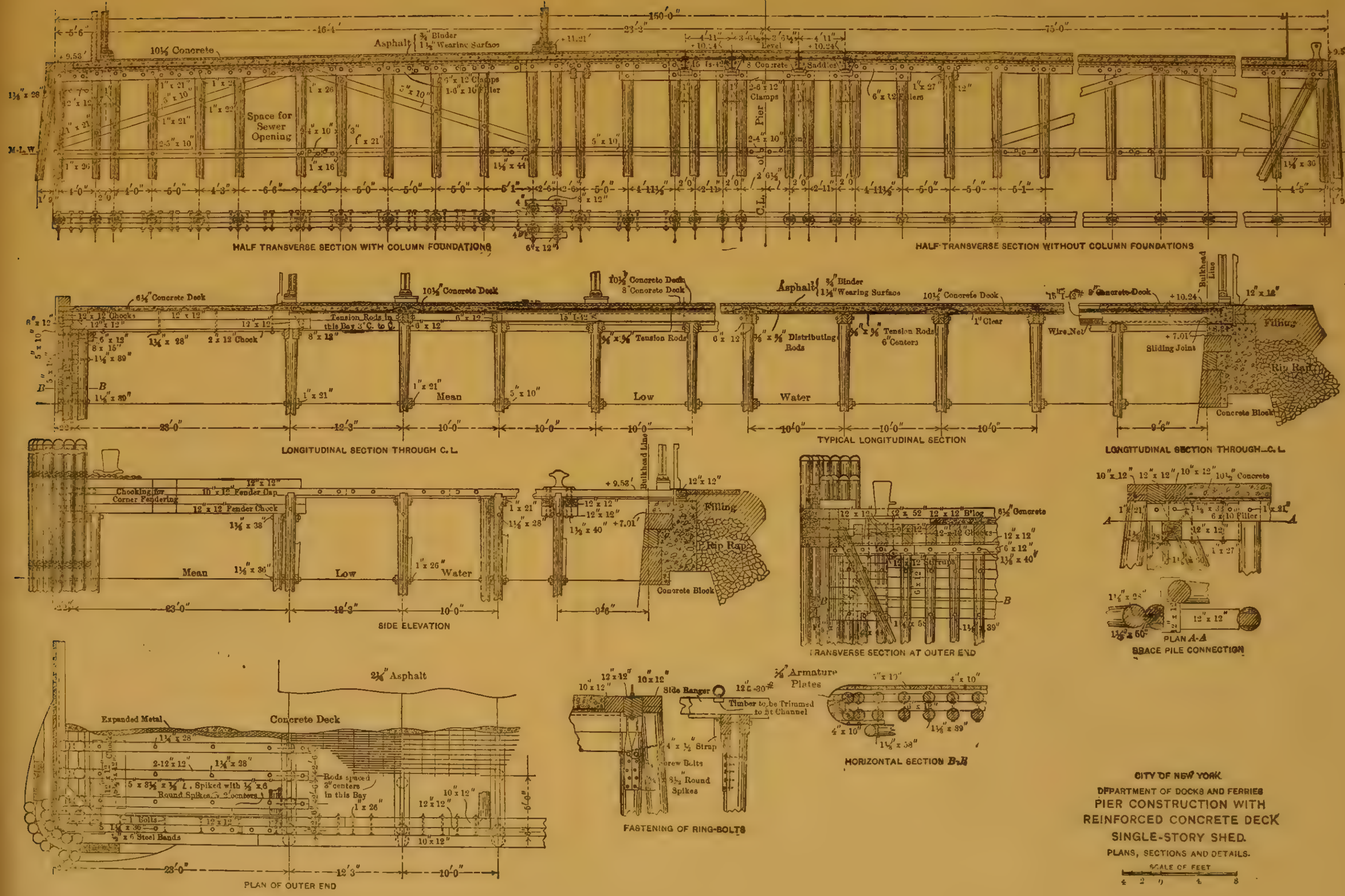
The wooden pier, consisting of a timber deck and floor system supported by timber piles, became the adopted type. It was cheap, durable, and readily adaptable to all classes of shipping. One of the most important characteristics of piers of this type is the ease and economy with which it may be removed entirely, reconstructed wholly or in part, or expanded at a low cost, to meet the increasing needs of commerce and shipping. A dock or system of docks sufficient to accommodate the shipping at the time it was built, might be found to be inadequate and obsolete within a comparatively short term of years, a complete re-arrangement being then necessary.

With timber structures, this transformation or reconstruction is a simple, rapid, and economical undertaking; it is difficult and costly with structures of stone, concrete, steel, etc. The use of concrete piles, reinforced concrete substructures or similar forms of construction, therefore, would not only have resulted in high first cost of construction, but the difficulty and expense incidental to the periodical removal, reconstruction, or expansion of dock structures of this type, as necessitated from time to time by the growth of shipping, would have rendered harbor construction work, as a revenue-producing municipal investment, practically impossible, and, consequently, would have greatly retarded the development of the harbor.

Types of Pier Construction.

The United States Government, by virtue of its power to control all navigable waterways in the country, established along the entire waterfront or shore line of New York Harbor two lines: one the bulkhead line, which limits the extent outshore of the solid filling or reclaimed land under water; the other, the pierhead line, which determines the limit to which piers may extend beyond the bulkhead line. These piers must be of such construction that the free flow of the tidal water shall remain uninterrupted by the supporting columns. This construction, being a condition wisely insisted on by the Government to preserve tidal conditions and currents, governs, to a great extent, the handling of vessels, particularly of large ones, and affects the sanitation of the City,

PLATE LXXII.
PAPERS, AM. SOC. C. E.
MAY, 1913.
STANIFORD ON
PIER CONSTRUCTION
IN NEW YORK HARBOR.



CITY OF NEW YORK
DEPARTMENT OF DOCKS AND FERRIES
PIER CONSTRUCTION WITH
REINFORCED CONCRETE DECK
SINGLE-STORY SHED.
PLANS, SECTIONS AND DETAILS.

in that it prevents the accumulation of sewage and refuse which would occur in closed slips. With open slips, such matter is carried away by, and disseminated in, the tidal flow. All pier construction is limited to the area included between the bulkhead and pierhead lines.

The pier which meets these requirements, and was adopted by the City in its early history as the type of structure for berthing vessels (and also adopted by all private and corporate interests), is a wooden structure throughout, consisting of a deck resting on piles driven into the mud or hard bottom. The physical features of the harbor, the geological formation of the bottom, and the condition of the water, fortunately permit the adoption of this type of construction, which, in many other parts of the world, is not adaptable because the life of the timber itself in the water would not be permanent or fairly long-lived. Wood-boring animals, the teredo, limnoria, etc., are very little in evidence, and, therefore, wooden piles are practically permanent below the water-line in almost all parts of New York Harbor.

The prominent objectionable feature to wooden pier construction is the expense necessitated by the constant repairs of the deck sheathing and the continuous wear and tear of the fender system extending along the sides and outer ends of the piers. As to the remainder of the structure, piles, floor system, etc., its maintenance and repair is very economical and consists generally in the replacement, from time to time, here and there, of decayed portions of the timber above mean low water only, at inconsiderable expense.

Until seven or eight years ago, the piers were generally built with decks of yellow pine, 4 in. thick, laid on a system of yellow pine floor structure of rangers and stringers. This deck plank in turn was covered with a second layer of either 3- or 4-in. plank sheathing, laid diagonally or at right angles to the deck proper, to form a wearing surface for the traffic.

Constant repairs and renewal of this deck sheathing, caused by the wear and tear of team traffic, is augmented in great measure by the moisture, horse urine, etc., which saturates the wood and eventually finds its way to the underlying deck and rangers. This forms the greatest item incident to the expense of pier maintenance, the average life of the sheathing for most busy piers being about 6 years, or requiring a 17% renewal annually. As the cost of the deck sheathing is generally about 12% of the total cost of a pier, it will be seen that these

sheathing repairs would aggregate 2% per annum of the cost of the entire structure.

New Pier Construction Practice.

Notwithstanding the necessity for constant repairs to the deck sheathing of the wooden pier, the parts of the remainder of the structure —rangers, caps, stringers, piles, and bracing—give excellent service. Maintenance is economical, the average life of the structure above mean low water line being from 20 to 25 years, the repairs aggregating an entire renewal above low water in that period of time. As the life of the piles supporting the structure is practically permanent when submerged below the water, the entire structure can be rebuilt after this period and made practically new by "bench capping" such piles as may be decayed above the water line and renewing the stringers, caps, deck, and sheathing; in other words, the pier structure proper, after a life of 25 years, is readily susceptible of renewal above the water line, the supporting piles below that line being to all intents and purposes permanent.

It will be readily seen that the life of the wooden pier structure would be prolonged still further, and the cost of maintenance and repairs reduced, by the elimination of the objectionable wooden deck sheathing and its replacement by some form of deck impervious to moisture and resisting the wear and tear of traffic.

It was with the object of eliminating this large repair expense incidental to the maintenance of the sheathing, and reducing maintenance cost generally, that the Engineering Bureau of the Department of Docks and Ferries, under the direction of J. A. Bensel, M. Am. Soc. C. E., then Commissioner of Docks, about seven years ago, began a serious investigation and study of the problem of producing a permanent deck surface supported by timber piles, assumed as permanent below the water line.

This study has resulted in the entire elimination of the old style of wooden deck in new structures, and the production of a new type consisting of reinforced concrete laid directly on the transverse cap system of the wooden pier substructure. This concrete is laid in slabs, spanning the pile bents practically as simple beams.

This new type of deck eliminates not only the 4-in. deck sheathing, but also the 4-in. deck proper and the underlying 12 by 12-in. yellow pine ranger system longitudinally of the pier on top of the transverse cap system, further increasing the life of the substructure.

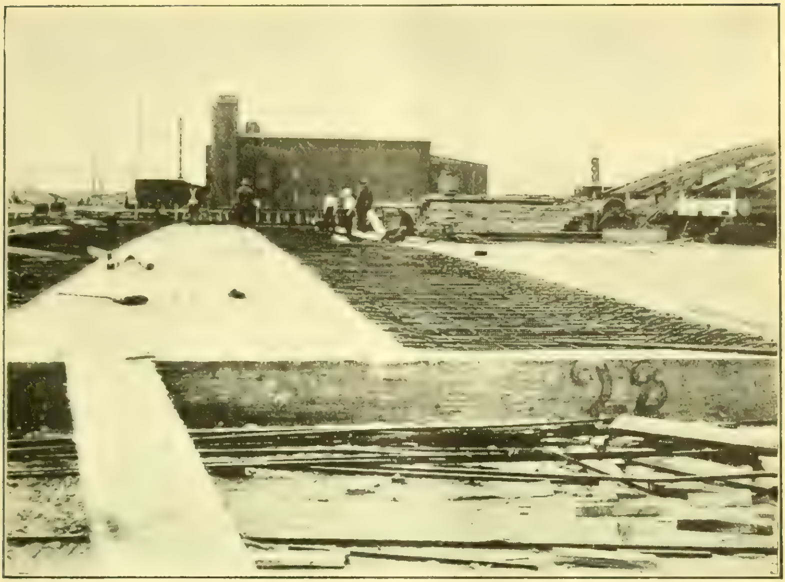


FIG. 1.—STRIP OF CONCRETE DECK AND STEEL REINFORCEMENT.

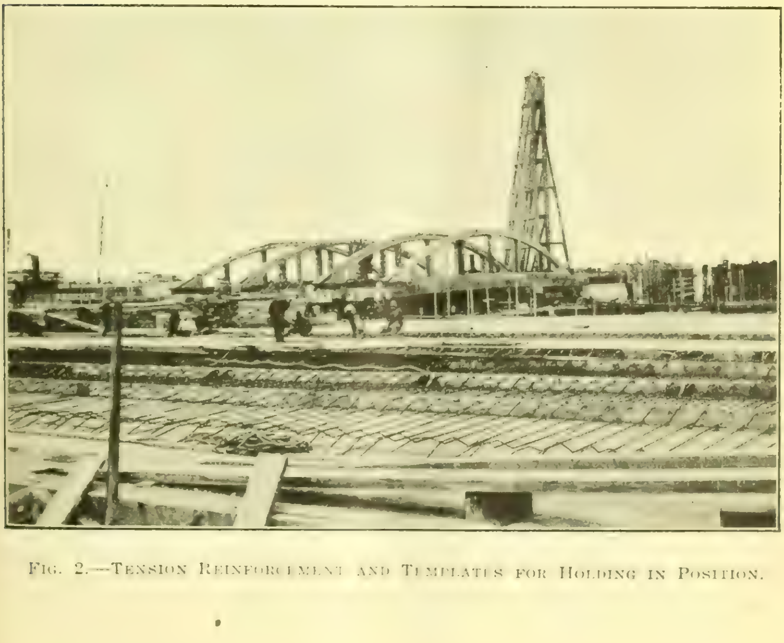


FIG. 2.—TENSION REINFORCEMENT AND TEMPLATES FOR HOLDING IN POSITION.

A structure was thus evolved which had a permanent deck practically impervious to the penetration of moisture to the substructure, readily renewable from low water to the under side of the concrete deck, and permanent below the water line, with a first cost about equal to that of the old wooden deck pier.

The first step in the elimination of the great cost factor, the renewal of the deck sheathing, was the replacing of this sheathing by a concrete wearing surface, from 4 to 6 in. thick, laid directly on the old type of timber decking. This type was used by the North German Lloyd and Hamburg American Steamship Companies in the reconstruction of their piers at Hoboken, and by the City of New York in the Chelsea Section piers, the result being a deck surface which is impervious to moisture and urine, and, therefore, a protection to the substructure, as well as a saving in maintenance.

The unit of cost of construction of a pier depends in a large measure on the size of the pier. As the outer portions, the sides, and outer end of a large pier are more rigid and heavier than those of a smaller pier, and, therefore, cost more in both labor and material, the relative cost per square foot of a short pier is considerably larger than that of a long one. The average cost of the old wooden deck pier of large dimensions is from $1.00 to $1.15 per sq. ft.

Further investigation and study resulted in the entire elimination of the wooden deck plank, deck sheathing, wooden floor rangers, etc., and the adoption of the present type of pier deck, as before mentioned, consisting of a reinforced concrete slab, $10\frac{1}{2}$ in. thick, extending from center to center of the transverse pile rows placed generally 10 ft. apart. This slab is designed to carry a live load of 500 lb. per sq. ft. for the 10-ft. span between pile rows, and is reinforced with $\frac{5}{8}$-in. square steel rods. The latter run longitudinally of the pier, are 6 in. apart, and are staggered so that only alternate rods terminate on the same pile row, with $\frac{3}{8}$ by $\frac{3}{8}$-in. separating rods. The slab is of 1:2:4 Portland cement concrete, with $\frac{3}{4}$-in. broken stone, the upper $\frac{1}{2}$ in. of the slab being of Portland cement mortar finished smooth. This rod reinforcement is intended to be standard, but the substitution of trade sizes of equal strength and efficiency is permitted, subject to approval.

Definite illustrations of this type of pier construction are found in the two new piers recently completed by the Department of Docks and Ferries at the Gowanus Section, South Brooklyn, one at the foot of

31st Street, 1 475 ft. long, and the second at the foot of 33d Street, 1 616 ft. long, each pier being 150 ft. wide. These piers are among the finest in the harbor, and are probably the largest of their type in the world. The unit cost is practically the same as that of the old wooden deck type. The decks have a crown of about 8 in., in order to shed the water. The inshore end of the concrete deck rests on the bulkhead wall, but is not attached thereto, a horizontal plane joint allowing the deck to slide on the wall as it expands or contracts on account of changes of temperature.

Twenty-six piers with concrete decks have been built by the Department during the past 7 years. The earlier type, as exemplified by the Chelsea Section piers, consists of a 6-in. concrete deck surface reinforced with expanded metal and laid directly on the deck planking. The next type produced omitted the deck plank, and is represented by eight piers with decks consisting of a concrete slab, 6½ in. thick, reinforced with expanded metal, the slab spanning yellow pine rangers running longitudinally of the piers and generally about 6 ft. apart.

The final type evolved, omitting the timber floor system entirely, and placing a concrete slab reinforced with longitudinal steel rods directly on the timber-capped transverse pile rows, is represented by eight piers, the most important examples being those at the foot of 31st and 33d Streets, South Brooklyn, and the Municipal Pier at Stapleton, Staten Island.

All these piers have been built where the condition of the river bottom underlying them was such that no settlement could occur, and they have behaved admirably. No repairs have been necessary, except to the fender system, and none are anticipated for many years to come, excepting the renewal here and there of an imperfect pile, where rot may appear above the water line. Such renewals can be made at a minimum of cost—a few dollars per pile—by bench-capping, without any interference whatever with the integrity of the reinforced deck itself.

Column Foundations.

For single-story sheds, where additional bearing strength is required in the new concrete deck pier for shed column or superstructure support, the question has been treated in general in the same manner

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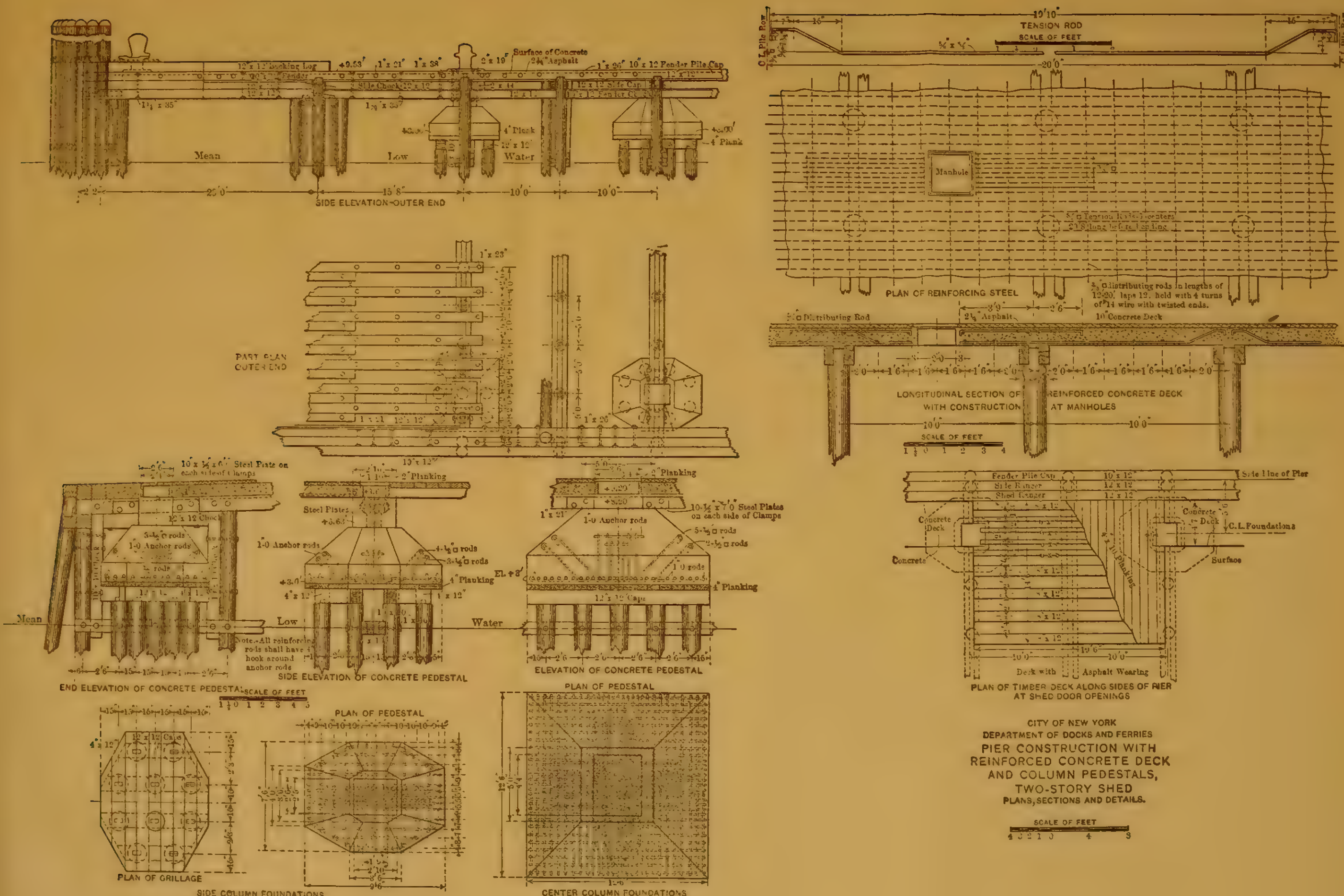
IN NEW YORK HARBOR.



CITY OF NEW YORK
DEPARTMENT OF DOCKS AND FERRIES
PIER CONSTRUCTION WITH
REINFORCED CONCRETE DECK
AND COLUMN PEDESTALS,
TWO-STORY SHED
PLANS, SECTIONS AND DETAILS.

SCALE OF FEET

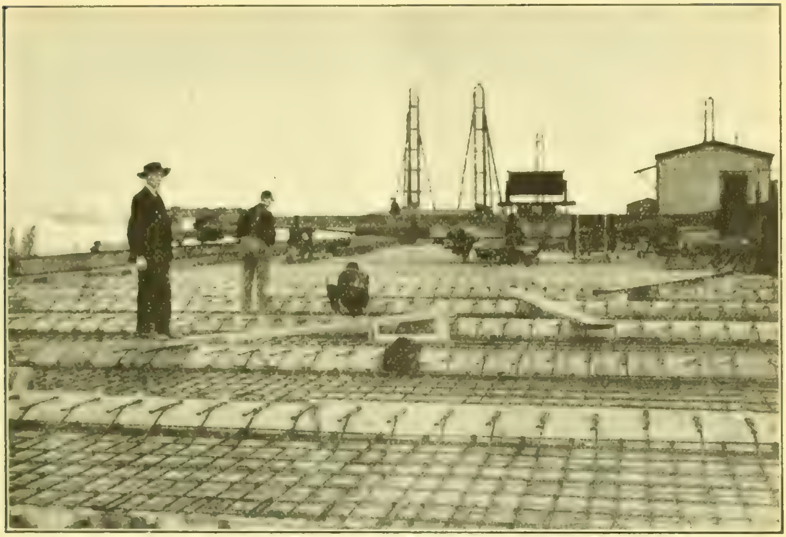


FIG. 3.—TENSION AND DISTRIBUTING REINFORCEMENT WITH TEMPLATES FOR HOLDING IN POSITION.

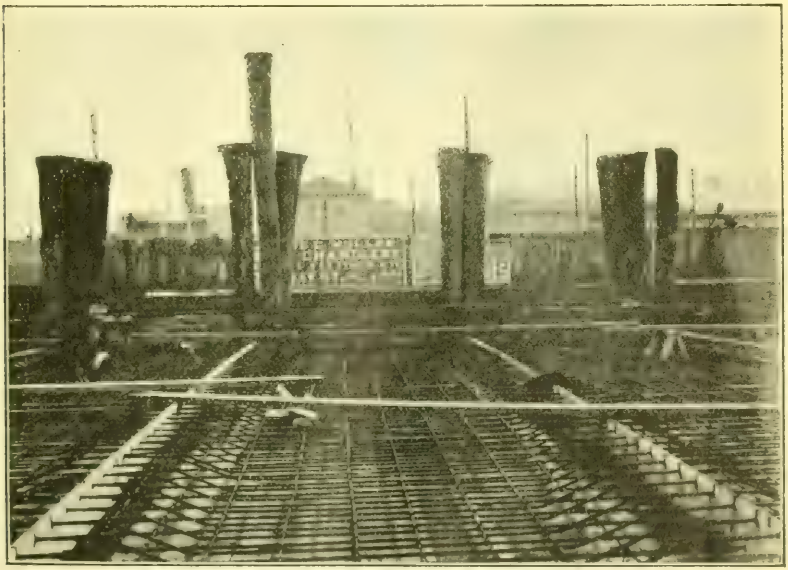


FIG. 4.—REINFORCEMENT COMPLETE, WITH TEMPLATES WHICH ACT AS FORMS FOR THE ALTERNATE STRIPS OF CONCRETE DECK.

as in other parts of the structure, that is, by adding the necessary number of piles to carry the load concentrations, assuming the piles to be permanent below low water and easily renewable above that plane.

Where heavier concentrations occur, as, for example, in double-deck or two-story sheds, the piles are cut off at or near low water and covered with a timber grillage; built on this grillage are reinforced concrete pedestals, extending to the deck level, to carry the shed columns.

Railroad tracks, being a requirement on the South Brooklyn piers previously described, are carried on four lines of 15-in. steel I-beams, placed on the transverse clamp system of the pile rows and extending from the inshore end of the pier sheds to within 60 ft. of the outshore shed wall. The beams rest on steel saddles placed on the clamps, and are entirely encased in concrete.

TABLE 1.—Cost of Construction, Maintenance and Repairs.

Average Cost of Construction of Wooden Deck Piers, $1.00 to $1.15 per Sq. Ft.

Repair Costs of Wooden Deck Pier.

Description.	Percentage of total original cost.	Renewal required.	Remarks.
Sheathing	12	Every 6 years.	
Backing log	1.8	Every 8 years.	
Fender chocks, including vertical sheathing	4	Every 10 years.	
Fender piles	4.7	Every 12 years.	
Decking	11.3	Every 15 years.	
Bracing	7.1	50% in every 20 years.	
Rangers and caps	24.4	50% in every 20 years.	
Piles	34.7	33⅓% every 20 years.	Above M. L. W. only.

Concrete Deck Pier.

Cost of construction, 31st Street Pier,
South Brooklyn, no asphalt surface, $0.87 per sq. ft.

Cost of construction, 33d Street Pier,
South Brooklyn, with asphalt surface, 0.97 " " "

Economy being a prime factor in its construction, it was decided to try out the concrete deck surface for wear and tear of heavy team traffic, and the earlier decks, therefore, were finished with a smooth mortar surface to receive this traffic. Two years of experimenting on these lines, determined the fact that though the concrete surface was

admirably adapted to light traffic, cargo handling by hand or motor trucks, etc., it could not stand the concentration of heavy team traffic confined within narrow lanes located generally in the center of the pier. The grinding and turning of heavily laden trucks inside these narrow lanes or zones gradually caused surface rupture of the top coat of mortar. It was, decided, therefore, to place an asphalt wearing surface on the deck, and this has proven very effective.

The piers, at the foot of 31st and 33d Streets, South Brooklyn, have been in service for about 3 years. No signs of cracking or other imperfections have appeared, and the piers, as a whole, are a complete success.

Repairs.

For the modern type of concrete deck pier, the cost of maintaining the fender system is about the same as that for the wooden pier; deck sheathing repairs are practically eliminated, except such minor asphalt patching as may be required, and can be considered negligible in a good asphalt deck under cover; the deck plank is eliminated; the life of the ranger and cap system is prolonged by the protection from moisture given by the impervious concrete deck, and the cost of maintenance and repairs, therefore, is reduced to a minimum.

Conclusions.

From the foregoing it will be observed that the problem which confronted the Department was the elimination of the timber deck and deck-supporting structure of the wooden pier, by the substitution therefor of some permanent form of construction meeting the following requirements:

(*a*) Economy in cost of construction and maintenance, the unit cost to be such as to produce or make possible a remunerative return on the capital invested.

(*b*) The construction to be of such character as to be readily extended, reconstructed, re-modeled, or, if necessary, entirely removed, as more intensive development of the area occupied by the pier or system of piers might be made necessary by the growth of commerce and shipping.

From what has been stated the following conclusions may be deduced:

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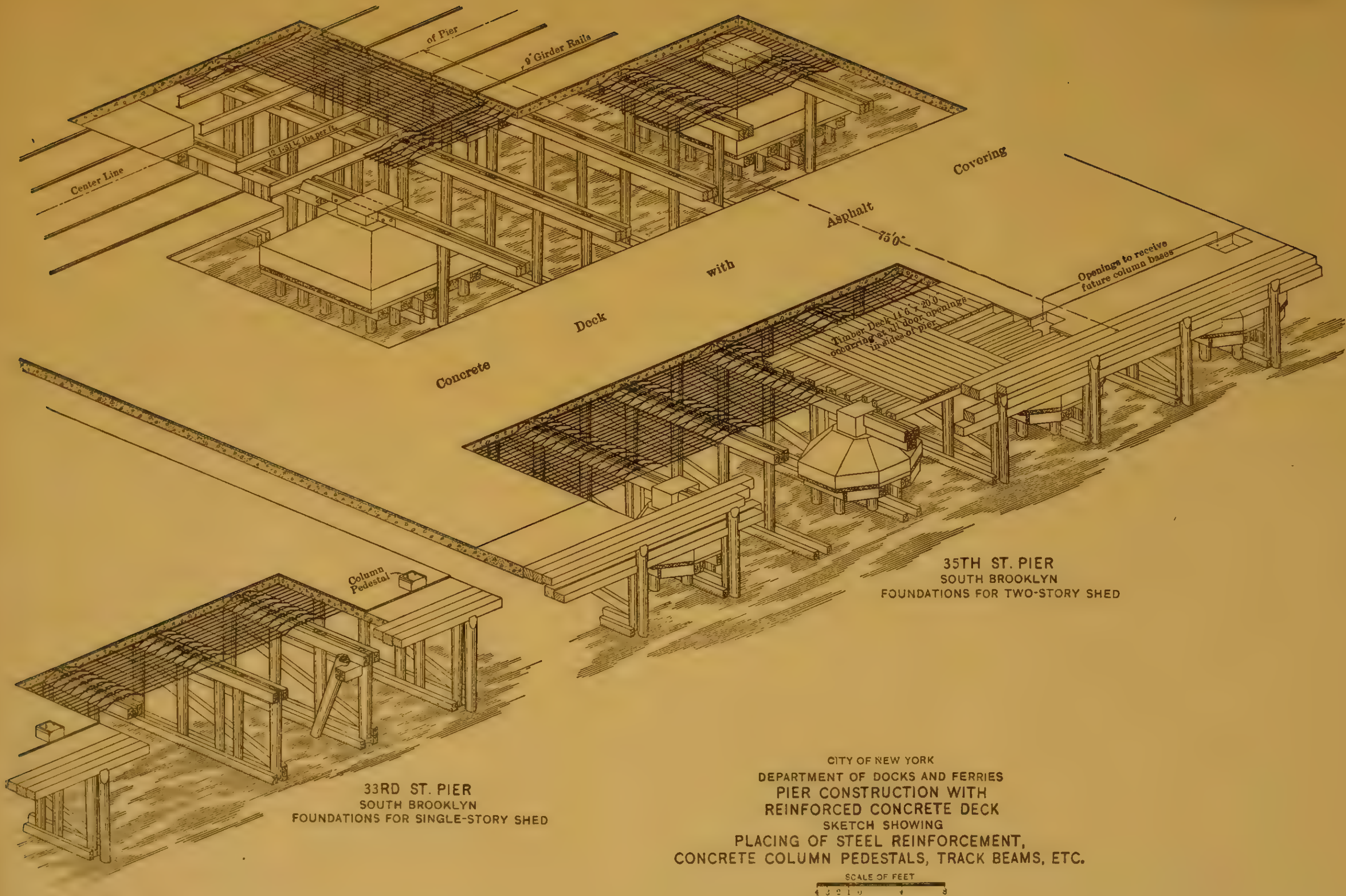
STANIFORD ON
PIER CONSTRUCTION
IN NEW YORK HARBOR.



CITY OF NEW YORK
DEPARTMENT OF DOCKS AND FERRIES
PIER CONSTRUCTION WITH
REINFORCED CONCRETE DECK
SKETCH SHOWING
PLACING OF STEEL REINFORCEMENT,
CONCRETE COLUMN PEDESTALS, TRACK BEAMS, ETC.

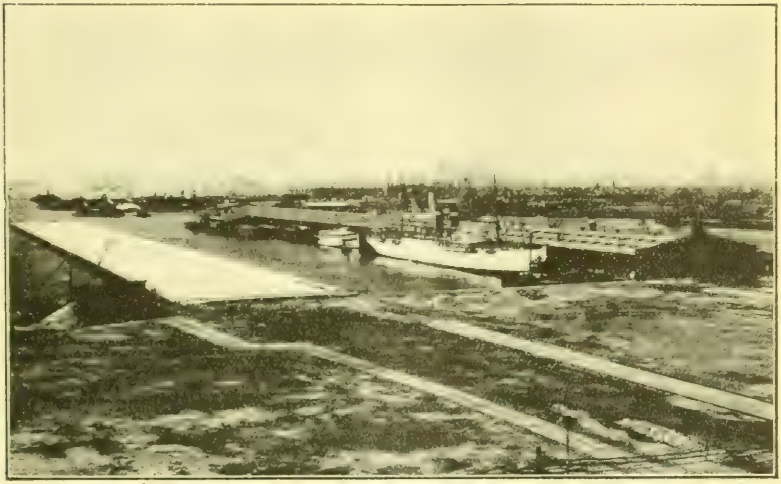


FIG. 5.—TWO PIERS WITH REINFORCED CONCRETE DECK, EACH 150 FT. WIDE. ONE 1 475 AND THE OTHER 1 616 FT. LONG.

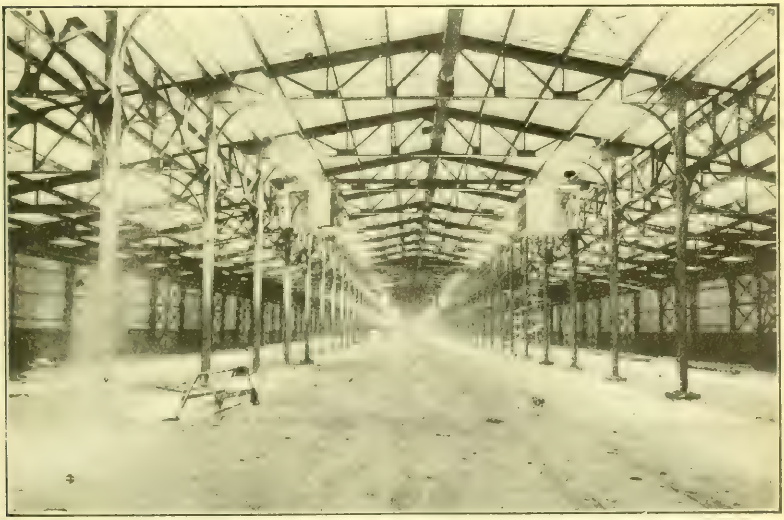


FIG. 6.—INTERIOR VIEW OF SHED ON PIER, 150 FT. WIDE AND 1 616 FT. LONG, SHOWING CONCRETE DECK AND TRACK STRINGERS, READY FOR RAILS.

First. Admitting that timber piles and foundation work are generally permanent below the mean low water line in New York Harbor, the Department of Docks and Ferries has met the requirements of the problem by producing piers having the following characteristics:

(*a*) The deck is absolutely permanent;

(*b*) The substructure, above mean low water, is easily and cheaply repaired and maintained;

(*c*) The supporting part, below the water line, is permanent; and

(*d*) The resulting structure is such that it can be readily extended, reconstructed, or, if necessary, entirely removed at a cost not prohibitive, as would be the case, for example, with most types of reinforced concrete deck-supporting structures.

Second. That the Department has produced permanent parts in the structures where these are essential. No attempt was made to obtain absolute permanency above low water, in the structure supporting the deck, for the reason that,

Third. This portion of the structure, the caps, piles, braces, etc., protected as they are from saturation by urine and other objectionable fluids by the concrete and asphalt deck forming a protecting roof, can be maintained in good condition at a very low cost.

Fourth. The type of structure produced, approximating permanency, is now being built by the Department at a first cost no greater than that of the former type of wooden pier throughout, and the cost of repairs and maintenance of the deck structure is almost entirely eliminated.

General Remarks.

The phenomenal growth of commerce and shipping in New York Harbor, producing constantly the need for additional wharfage room, has necessarily resulted in projects for dock and wharfage improvements, covering extensive portions of the water-front and involving enormous amounts of money.

As such development should be made revenue-producing, it follows that a cheap type of pier construction, low in first cost, long of life, and economical to maintain, is one of the fundamental factors in determining the extent of the improvements undertaken not only by the City

of New York, but by private interests as well. This does not necessarily follow when smaller cities are considered.

Compared with the vast amount of money necessary for the comprehensive development of the port, the sums required for similar purposes by other ports on the Atlantic and Pacific seaboards of the United States are very small, in fact, in many cases, comparatively insignificant. Harbor improvements at these ports are generally confined to a limited area or extent of water-front, and consist usually of a few piers or bulkheads. Their aggregate cost is such that, even if not revenue-producing, the investment is often well within the financial capacity of the municipality and wisely undertaken by reason of its effect in stimulating existing trade and attracting new shipping business, producing what might be called "indirect revenue." This has often been the incentive in inaugurating harbor improvements at these minor ports, and it has resulted, in some instances, in absolutely permanent structures at such great expense that remunerative return on the capital invested is highly improbable, if not impossible; in other words, the benefits derived are being consummated at too great a cost, even when considered from the point of view of "indirect revenue."

Notwithstanding the many desirable features of this new type of pier construction, it has not been generally adopted, though many inquiries and requests for plans and descriptions of the type and method of construction have been received and replies made thereto, pointing out its proven economy in first cost, repairs, and maintenance. New York Harbor, however, presents a number of examples of similar types of concrete deck piers adopted by private interests, notable among which are: The reinforced concrete deck pier built by the Central Railroad of New Jersey at Communipaw, N. J., 892 ft. long and 131 ft. wide, used for railroad freight, tracks being laid on the pier deck; the pier under construction by the United States Lighthouse Board in the Reservation at St. George, Staten Island; and in two piers now under construction at the Brooklyn Navy Yard. The design of the latter, particularly, presents an admirable combination of reinforced concrete construction, surmounting the wooden pile and grillage supporting foundations near low water, resulting in a practically permanent pier at an economical first cost.

When reinforced concrete piers have been built at other ports along the coast, the attempt at absolute permanency, as stated above, has gen-

erally resulted in prohibitive first cost, when considered as a business proposition requiring interest on the capital invested.

Where the life of the wooden structure below the water is not endangered by wood-borers—in other words, where it can be considered as permanent—the difference in cost between an elaborate reinforced concrete pile and deck-supporting structure throughout, and a structure of the type herein described, represents practically that amount of money uselessly wasted.

Further, it is an open question whether the rigidity of a reinforced concrete structure throughout would not be a serious cause of deterioration in such structures, particularly below the water line. The shearing action of the impact of a large ocean-going steamship with a pier of this rigid type might cause a dangerous condition in the entire structure difficult to repair or overcome; even shocks tending to break the concrete surfaces of piles and substructure would admit sea water with its consequent destructive chemical action and freezing in cold weather.

On the other hand, the timber and pile substructure, with its flexibility and elasticity, acts, to a considerable extent, as a shock absorber, dissipating the effect on both the vessel and the pier, consequent on the impact of the collision or more or less violent contact with the pier, sometimes occurring when warping vessels into their berths.

The personnel of the Department of Docks and Ferries, as at present constituted, is as follows: Mr. R. A. C. Smith, Commissioner; Bureau of Engineering: The writer, Chief Engineer; S. W. Hoag, Jr., M. Am. Soc. C. E., Deputy Chief Engineer; and R. T. Betts, M. Am. Soc. C. E., Assistant Engineer, in charge of design.

AMERICAN SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

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PHYSICAL VALUATION OF RAILROADS.

By William J. Wilgus, M. Am. Soc. C. E.

To be Presented October 1st, 1913.

The Herculean task of valuing the railroads of the United States is of vital importance to the entire nation, whether viewed from the standpoint of rate regulation or its possible outcome, government ownership. The vastness of the interests involved and the effect that the result may have on social conditions, make imperative the adoption at the outset of underlying principles and methods which will appeal to the public and the Courts as being fair and equitable.

It is with the object of promoting a discussion that will be of aid to those burdened with the accomplishment of this task that the writer ventures to advance certain opinions which are the fruit of his experience in the valuation field.

Basic Principles.

There are several ways of determining physical value, depending largely on the purpose for which the result is to be used.

Sale Value.—In taxation matters, the sale value method has been used, right of way and real estate being taken at their assessed valuation, and other items at their depreciated or second-hand value, without the inclusion of overhead and development costs.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

In New Jersey this method was adopted in compliance with the general tax law of the State, the expert in charge of the valuation stating in his report as follows:

"Since the real estate and personal property are to be inventoried and appraised separately from the franchise, it seems manifest that it is our duty to consider all of the thousands of parts and items of the property owned by each of the several railroads, entirely apart from their value as considered in the composite whole cemented together by the charter or franchise."

In referring to the fixing of land values, he says:

"We have the right to assume, however, that since the several assessors are elected or selected by the taxpayers of their respective communities, they must have had sufficient experience in land values to entitle them to assess the property in their respective districts, and that, therefore, they are the best available source of information concerning the going price or 'true value' of the land in their districts; and, since the several taxing districts are content to accept the opinions of these assessors as to the 'true value' of the property of individuals, corporations (excepting railroad corporations) and firms, we should give considerable weight to the opinions of the several local assessors when considering the 'true value' of land."

Also:

"No per cent. has been added to the value of lands in excess of the value in exchange for money, as near as such value can be determined by the exchange price of lands adjoining the lands of the railroad in each particular taxing district, and at each particular point where such lands adjoin railroad lands."

While the New Jersey procedure was proper under the conditions there prevailing, it yielded results entirely at variance with those obtained in other States where different theories have guided the appraisals.

Certainly, the sales value principle of treating the component parts of a property as uncorrelated items, at prices that they would bring if thrown on the market, is not applicable to the ascertainment of the full value of the tangible property of railroads as going concerns.

Original Cost to Date.—In the Act of Congress that prescribes the alternative methods under which the Interstate Commerce Commission is to proceed, Original Cost to Date is named, in which the actual cost of property, as reflected on the books and records of the companies, is to be taken.

With rare exceptions, it is extremely doubtful that the books and records of the railroads of the United States will be found to be dependable for the purpose of ascertaining present-day fair values. Only in recent years have cost accounts been kept in a uniform and complete manner, and even then the almost universal tendency has been to understate charges to construction, and to additions and betterments. This is particularly true on systems that are the product of gradual expansion over terms of many years. Interest during the period of construction, organization and administrative expenses, supervision, freight charges, and the use of equipment on extensions of main line and branches, in many, if not the majority of, instances, have been largely or entirely absorbed in the running expenditures of the parent company, and are not reflected in the book costs. On the older lines the accounts of many of the constituent roads have been lost or are incomplete. Additions and betterments have been charged to operating expenses. Roads have been absorbed through foreclosure proceedings, and the cost has been entered on the books at figures much less than their original cost. In fact, all that can be said of the surviving books of the older railroad systems is that they show merely such portion of the original cost to date as is there recorded, and that, therefore, they are not proper for use in physical valuations, except in so far as they may be of aid in casting a side light on estimated costs of reproduction as of the present time. Moreover, the loss of old records on many roads, and incompleteness of records on others, would necessitate frequent departures from the general rule, with resulting inconsistencies and injustice.

Cost of Reproduction New.—The second of the alternative methods prescribed in the Act of Congress is Cost of Reproduction New. Under this theory of valuation, as generally construed, the configuration of the ground surface and other natural topographical conditions along the line are assumed to be restored and be as they were before the railroad was constructed, but in all other respects the existing environment is taken as of to-day.

In determining quantities and values under this method it would seem essential that, as far as possible, the procedure should be duplicated that experience has shown would have to be followed, step by step, in the creation of a going railroad. Mere inventorying of the innumerable component items and the placing of a price on each will

not give the cost of reproduction, because the intimate relation that the parts bear to each other and the cost of their assemblage into a connected whole are thereby ignored.

The impression prevails that the building of a railroad begins with the breaking of ground and ends with the driving of the last spike. The fact is that there are three well-defined and equally important stages that precede the successful completion of a solvent enterprise, the first and last of which are given but little weight in the usual estimating of cost.

First there is initiation. The plan has inception in the minds of men who are fitted by experience, acquaintanceship, resourcefulness, courage, and tact, to give it life and sustain it through many vicissitudes to final issue. Reconnoissances, preliminary surveys, and estimates of cost, revenue, and profits, are needed to demonstrate its feasibility. Tentative agreements are essential for the features that must be secured before publicity. Arrangements must be concluded for financing the project through underwritings or by sales of securities on a commission basis. Capable men must be selected for the administrative and engineering staffs. All this requires much time, often years, and considerable expenditures which the Interstate Commerce Commission has authorized as chargeable under its classification of "47, Interest and Commissions" and "48, Other Expenditures."

Next comes the constructive stage. This embraces final location, investigation of subsurface conditions, and surveys; the preparation of maps, plans, specifications, and estimates; the purchase and condemnation of rights of way and real estate; negotiations with other railroads for trackage and crossings, and with municipalities and towns for franchises and other privileges; the requesting of bids and the awarding of contracts; and then active construction by contract and company forces.

The acquisition of land and of rights from others is a slow and tedious process, fraught with delays and expensive litigation, and it is rarely safe to proceed with actual construction on important work until this step is concluded.

Construction proper necessarily would not be started simultaneously on all portions of a large system. The main stem would require first attention, followed soon by the important terminals, next the

principal branches, then the lesser ones, and lastly the minor branches and spurs.

Expeditious construction of a great railroad system through populous communities does not admit of the awarding of small contracts, as is usual on minor extensions of a "going" railroad. Responsible contractors of wide experience, with followings of sub-contractors, must be attracted by the prospect of work of magnitude at remunerative prices.

Lastly is the educational and development stage, when the line is opened to traffic. Competent forces must be selected, organized, and trained to maintain and operate tracks, structures, rolling stock, and floating equipment. Errors of design and construction, as developed by operation, must be rectified. Equipment in consignments must be received from the manufacturer, "broken in," and assigned to varying duties. Traffic must be induced, economies studied, experiments tried, and the public brought to an appreciation of the new facilities. Stated differently, all parts of the new creation must be co-ordinated and thoroughly trained in their new duties before it is possible to handle successfully a great volume of traffic. This period of education, adjustment, and development, during which the earnings from operation would increase from nothing at the commencement to the full amount at the end of the period, varies, of course, with the nature of the country and traffic. Under the most favorable auspices, it usually lasts for several years.

It is evident that the mere inventorying of the items of a railroad as parts of an inert whole will not give due weight to the processes that experience has shown are essential to the creation *de novo* of a vitalized homogeneous system of transportation, equipped, manned, and trained for the same character of service that it now performs. The problem should be approached in much the same spirit as in the actual organizing, building, and launching of a new railroad.

Cost of Reproduction, Less Depreciation.—The remaining method mentioned in the Act is Cost of Reproduction, Less Depreciation. For rate-making purposes it does not seem to the writer that the physical depreciation should be deducted from the cost of reproduction new. Both law and practice have determined that all expenditures for renewals and repairs should be charged to working expenses, and not to capital; or, stated differently, normal depreciation is not to be

treated as a wastage of capital, but as an element in the cost of operation that is covered by the rate.

That any other course would be improper and even illogical is at once apparent when it is realized that in any subsequent reappraisal, say a year hence, the inclusion therein at full value of a renewed item that appears in the appraisal at its depreciated value, practically would amount to the capitalizing of a renewal expenditure that had been charged to income.

In fact, the Act, in requiring that valuations shall be revised from time to time as improvements or other changes are made, in effect prohibits the deduction of depreciation, as otherwise the constant addition of amounts expended in the replacement or renewal of items that had been included in the valuation at their depreciated price, would be a violation of the rule of the Interstate Commerce Commission that operating expenses should not be charged to capital.

For instance, expensive coal pockets which will cost, say, $600 000 to renew, may be worth a nominal sum in their present-day run-down condition. The adoption of a depreciated figure would mean that when the structure is rebuilt, say, next year, $600 000 would be added to the valuation, although correct accounting would demand that the entire cost should be charged to operating expenses.

The conclusion seems warranted that, for rate-making purposes, depreciation should not be deducted from the cost of reproduction. It is plainly a liability of the stockholders, partly offset by any reserves that may have been established for that purpose, and should be given due weight in determining a railroad company's net profit and loss account. Of course, in the case of Government acquisition, this feature would require due attention, for the reason that the purchaser would be assuming the stockholders' burden of future restoration of depreciated items.

Summary of Basic Principles.—If the foregoing reasoning is sound, it is evident that the selection of the underlying basic principle must be guided by the purpose for which the valuation is made.

The sale-value method, while used in certain instances where the general taxation laws thus require, is inapplicable for rate-making and acquisition purposes because it does not take into account the features that mark the difference between an aggregation of dissociated parts

and the same parts cemented together and pulsing with life as a going concern.

The original cost-to-date method is inadmissible, except as a side light on other methods, because the incompleteness and non-uniformity of past records are a bar to the making of accurate statements of full cost, and because the loss of such records on many roads makes impossible that universality of application that is essential to equity and fairness.

Cost of reproduction new, if estimated in such manner as to embrace all the steps that experience has shown are needed for the creation of a living, self-supporting organism, may be considered as a fair measure of physical value in connection with rate regulation; but physical depreciation, being an element of waste chargeable to operating expenses and therefore a stockholders' liability, is not deductible except in cases where the burden of restoring the depreciation is transferred to a purchaser.

LAND VALUES.

Even though the reproductive principle is accepted, there are many who contend that land values should be entered in the estimate at their original cost, or at the current normal market price of neighboring lands, without any increase for severance and other damages, or for the excess that railroads are compelled to pay for right of way.

Original Cost.—The "original cost" measure of land values is believed to be unfair for two reasons: It ignores the increment that is enjoyed by all other property owners through increase in the population and prosperity of the country; and it would lead to the inconsistency of low original values on lines unfortunate enough to have preserved their land records, and high costs on adjacent lines where the absence of records would make imperative the use of present-day values.

Current Normal Market Prices.—That current normal market prices are not a proper gauge of the cost of reproducing railroad lands is well known to all who have had experience in right-of-way matters. From a variety of causes, such as severance and other damages, plottage, and the psychological attitude of owners toward corporate purchasers, the prices paid by railroads are far in excess of normal neighboring values, in cities and towns the average factor ranging from $1\frac{1}{3}$ to 2, and in the country from $2\frac{1}{2}$ to $3\frac{1}{2}$. To ignore this condition

is unjust in theory, and in practice would result in confiscation of property where actual expenditures for right of way on recently built lines can be proven to have been many times the cost that would result from the use of fictitious "normal market prices."

Reproductive Prices.—The conclusion seems warranted that strict equity can be served only by the adoption of one standard of land values applicable alike to all roads, and that the fairest standard is reproductive cost, which, as its name implies, calls for the estimated cost of reproducing the lands in each locality at the present time, taking into consideration all the elements which are known to have a bearing on the purchase of railroad right of way and real estate, including costs of acquisition.

This method guarantees equal consideration to the older lines and to those more recently built, avoids the dangers of confiscatory action, and gives due consideration to the facts that are known to enter into the purchasing and condemnation of lands for railroad purposes.

Inventorying and Pricing Measurable Items.

A physical examination of a railroad at once reveals a multitude of items which are patent to the eye and, therefore, may be termed "measurable items."

Interstate Commerce Commission Classification.—To estimate properly the cost of reproducing these items in place, as parts of a connected whole, it is exceedingly necessary that they shall be listed in such a manner that their relation to each other will be apparent; and this can be best done by adhering strictly to the classification of expenditures for road and equipment, as prescribed by the Interstate Commerce Commission. In fact, this procedure is imposed under the terms of the Act.

A number of valuations have generalized their treatment of the data embraced under the primary accounts of the Commission, with results that will not bear analysis. For this reason it is essential that every road item should be entered under its proper sub-primary account, exactly as would be done in the building of a new line. Bunching items together at lump prices will not accomplish this result.

Tentative Prices.—By inventorying all parts, with a view to their relation to each other during the process of construction, and by adhering strictly to the Interstate Commerce Commission classification, it is possible to determine in advance of the field work a list of tenta-

tive prices for all the items chargeable to each of the sub-primary accounts that actual experience has shown will be encountered.

As conditions on many railroads in various parts of the country differ widely, each locality requires special study in conjunction with such records of actual cost as may be available. Based on this study, a tentative price list may be adopted for the general information and guidance of the engineer in direct charge of each railroad subdivision. Such prices would be modified by him whenever local conditions made that course necessary, and in such cases his reasons for the modifications should be given for *visé* by the engineer in general charge.

In fixing tentative prices, due consideration should be given to many elements of cost which are of a temporary nature during construction and are not always apparent in after years, as, for instance, salaries and expenses in connection with the acquisition of lands; temporary trestles to facilitate track-laying in advance of the erection of bridge superstructures; preliminary surfacing of track for the preservation of rail from injury pending final ballasting; and transportation of men, tools, and material to points of distribution, the expenses of which are best incorporated in the unit prices rather than to attempt to segregate them under Interstate Commerce Commission Account 32.

Owing to wide fluctuations in the costs of labor and material, the practice of adopting unit prices that will be fair averages over a period of several years has been followed extensively. This is undoubtedly the proper course, with the exception of items that have shown a constant tendency in one direction, as in the cases of lumber, piling, ties, and many classes of labor. In the latter instances, it would seem that current instead of average prices should be adopted.

Overhead Costs.

(Exclusive of Interest During Construction.)

As already stated, the inventorying and pricing of measurable items by no means yield the full cost of reproducing a railroad.

The necessity of providing means for cementing together these items is recognized by the Interstate Commerce Commission through certain accounts in the classification of expenditures for road and equipment, viz.: 1—Engineering; 35—Earnings and Operating Expenses during Construction; and 43 to 48, inclusive, General Expenditures.

An estimate of the cost of a railroad also requires an allowance for contingencies, which the fallibility of the best of engineering forecasts has shown to be necessary to cover omissions, errors, and uncertainties.

In the aggregate, these overhead expenses constitute a large percentage of the total cost.

Engineering.—It should be borne in mind that Interstate Commerce Commission Account 1 calls for engineering expenses in connection with Road Items 4 to 31 only, and does not apply to Items 2—Right of Way and Station Grounds, and 3—Real Estate, nor to Items 37 to 42, inclusive, Equipment.

Contingencies.—Despite the utmost care in estimating, experience has shown that final costs are invariably far in excess of preliminary forecasts, unless a percentage is added to cover a multitude of contingencies that arise during the prosecution of work.

An honestly prepared estimate never over-states quantities, but, on the contrary, omits many which are overlooked or escape attention.

Claims are made by neighboring land owners, employees, contractors, and others that frequently involve lawsuits.

Condemnation proceedings result in awards for damages far in excess of usual anticipations.

Floods, wash-outs, and errors of employees cause added expense.

Delays are sure to arise that enhance costs, as, for instance, through strikes, court proceedings, and difficulties in securing labor and materials, and also through increased interest charges pending the time of final completion.

Finally, there is always the danger of rising markets for material and labor, and of a scarcity of high-grade contractors.

Of recent years there has been a growing appreciation of the necessity of adding for contingencies not less than from 15 to 20% to carefully prepared preliminary estimates of cost. The instances are many where enterprises have under-estimated their cash needs, through inadequate allowance for this feature, with disastrous financial results.

It has been said that the knowledge gained from the study of a completed railroad largely eliminates elements of uncertainty. This is true of such features as adequacy of waterways, miscellaneous items often forgotten or overlooked in a preliminary estimate, and, to some extent, nature of foundations and classification of excavation; but the

largest elements of chance still remain, such as claims, delays, rising markets, scarcity of competent contractors, omissions, inflated land values and damages, complications in connection with the elimination of grade crossings, and the nature of foundations of which, on the majority of the older roads, little authentic information now exists.

There are also the further items, usually unprovided for elsewhere, of cost of acquiring lands; the expense of organizing maintenance and operating forces pending the commencement of regular operation; and expenditures for engineering, inspection, and "breaking in" of rolling stock.

General Expenditures.—In the words of the Chairman of the Public Service Commission of New York in the Rochester, Corning, Elmira Traction Company decision:

"When the amount of the actual cost of the physical construction of the proposed road has been determined we are still far from having determined the amount of capitalization which should be allowed. There are many elements of cost attendant upon bringing into existence of a new railroad additional to the cost of mere physical construction. Some of these elements may be enumerated as follows: (1) expense of organization, (2) incorporation tax, (3) expense of obtaining a certificate of public convenience and necessity, (4) preliminary engineering expenses, (5) expense of procuring the authorization of issue of stock and bonds, (6) expense of marketing the securities, (7) discount upon the bonds provided they cannot be sold at par, (8) interest upon the bond issue during the period of construction and prior to the beginning of operations, (9) compensation of officers of the road during the construction period, (10) incidental expenses during construction period, (11) expense of obtaining local franchises and consents.

* * * * * * * *

"Another subject of great interest and importance is the compensation, if any, to which the promoters of the enterprise should be entitled for their services. Promotion has been so extensively abused and has been so universally used as a cover for abuses in capitalization that it has come to be regarded as a term of reproach and as a device to work schemes of robbery upon the investing public. No reason is apparent why this should necessarily be so. The honest services of a capable promoter are indispensable to the flotation of every comprehensive and far-reaching scheme of development in the railroad world, or elsewhere. A clear vision to see opportunities, ability to demonstrate them to others, and energy to push to completion works untried but of great moment, are indispensable to material develop-

ment and should be fairly and even liberally rewarded by the public which receives the benefit of those works. Such rewards, however, should be put upon a clear basis of business principle, should be of sufficient magnitude to encourage rather than discourage enterprise, and should not be so great as to make exorbitant demand which is perpetual in its nature, upon the community to be served. They are to be treated simply as just payments for services performed for the corporation, which services are valuable and in many cases even indispensable. Such services should be paid for upon the basis of what they are fairly worth, having regard to all the circumstances of the case.

"These observations are so elementary that further elaboration of the principle involved should not be necessary. * * *"

The Interstate Commerce Commission classification of expenditures for road and equipment provides for the charging of general expenditures to the following accounts:

43—Law Expenses;
44—Stationery and Printing;
45—Insurance;
46—Taxes;
47—Interest and Commissions;
48—Other Expenditures.

It has been usual in the valuation of public utilities to fix arbitrarily a percentage of the total cost to cover these items, but it seems possible to make an analysis of these charges and thereby reach a result that may be said to have a logical basis.

Law expenses, stationery and printing, and insurance may be estimated by taking the aggregate annual current expenses for these items on a given railroad and making a suitable allowance for the additional expense that would be probable under the conditions of construction, as compared with normal operation, for one-half the adopted total period of construction from the inception to the final completion of the enterprise.

Taxes during the constructive period may be taken at the current annual amount for one-half of the period extending from the date of commencement of right-of-way purchases to the time of commencement of operation.

Discount on bonds by many is not considered to be properly chargeable to cost of construction, on the theory that pure discount is equiva-

lent to an adjustment of the interest rate to current market conditions. A banker's commission for the sale of securities, however, should be included. Payment for the services of those undertaking the sale of stocks and bonds seems to be just as legitimate and necessary as compensation for other services incident to the carrying out of the project.

"Other expenditures" may be obtained by taking the current annual cost of salaries and expenses of general officers and clerks for one-half of a period extending from the commencement of right-of-way purchases to the commencement of operation. In addition to this there would be the further payment properly due to those who, through their initiative, originality, ability, and assumption of responsibility of final success, would give life to the enterprise. The propriety of making this allowance is well expressed in the above-quoted opinion of the Chairman of the Public Service Commission of the State of New York.

Interest During Construction.

It is generally conceded that interest on money during construction is as much an element in arriving at the cost of the reproduction of a railroad as expenditures for any other purpose in achieving the same result. Payments for the use of money are in principle not different from payments for labor, or materials, or right of way. During the process of construction of a new enterprise there is no fund on which the company can draw for interest payments, except interest-bearing borrowings supplemented by such net earnings as may result from operation during that time; and hence the capital raised must be sufficiently large to cover all items of cost, including interest upon itself, and "interest on the interest," up to the point of final completión of the road in running order.

Methods of Calculating Interest.—Although the propriety of including interest on money during construction as an element of cost is thus recognized, the tendency has been greatly to under-estimate the amount.

It has been customary to take the estimated cost at the adopted rate of interest for one-half of the assumed period of construction. This treatment is on the theory that the expenditures will increase in a constant ratio or straight line, from nothing at the beginning to the full amount at the end of the constructional period; that money ad-

vanced to the company is non-interest-bearing until actually disbursed; and that no interest is paid on the interest payments.

An analysis of the conditions that actually obtain in the building of a large railroad shows that the usual method of calculating interest charges yields a result very much lower than would actually occur in a reproduction of the system, for the following reasons:

1st.—Expenditures do not increase in a constant ratio. In the preliminary stage the rate of expenditures is small. Then there follows a marked rise because of heavy right-of-way payments, followed by a somewhat decreasing rate. Finally, the rate again increases by reason of large payments for equipment. The usual result is a much larger volume of expenditures in the early stages of the work than appears from the use of the straight-line method.

2d.—The securing of capital on a basis that will assure its delivery exactly as needed for disbursement during the progress of the work is not practicable. Stringency in the money market or other unforeseen contingencies make imperative the possession by the company of ample funds to bridge over temporary crises, even when the funds are supplied through banking houses of unquestioned strength. Either the entire amount must be taken at the time of financing, or the capital must be paid in annual installments in advance. In either case the unused surplus over current needs is loanable at rates materially less than those paid by the company, the effect of which is an addition to the burden of interest charges during construction.

3d.—Interest charges must be paid from the capital, which itself is interest-bearing, and therefore it is not proper that interest on the interest should be omitted from the calculation of this item of cost.

Summarizing, the ordinary method of calculating interest charges usually produces an amount that is too low, by reason of the failure to take into consideration the heavy right-of-way expenditures in the early stages of the work; by reason of the neglect to include interest on unused money awaiting active use; and by reason of the omission of interest on interest.

Rates of Interest.—The rate of interest paid on the money invested has been usually taken at 6%, on the theory that the enterprise would be financed one-half on bonds bearing 5% and one-half on stock en-

titled to 7%, both bringing par on the market. Many examples can be quoted to show that this rate is conservative.

The rate received on balances placed on time loans may be taken at from 4 to 6%, and on call loans at from 2 to 4 per cent.

Time of Construction.—The assumed periods of inception, right-of-way purchases, active construction, and traffic development should be based on conditions as found on the particular railroad under consideration. On a complicated system, the time required for the acquisition of right of way and for the construction of the more difficult lines should govern, and the assumed date of commencement of active work on the less important lines and branches should be advanced so that sufficient time only will remain for their completion when needed for the initial operation of the system as a whole. Industrial spurs as well as equipment may be assumed to be supplied during the final stage when traffic is being gradually induced. By treating the subject in this manner the building of the various sections and the delivery of equipment will be co-ordinated with a view to completion only as needed, and the undue expenditure of interest on inactive capital thereby will be avoided.

Graphical Analyses.—To assist in determining the lengths of the different stages, and in ascertaining aggregate capital requirements and net interest payments as the work is assumed to progress, graphical analyses will be found to make this important subject clear and conclusive.

Earnings During Construction.—Proceeding on the theory that the full current net operating income of a railroad will be realized at the end of the last stage of construction, it is, of course, proper that the capital invested should be credited with the net earnings enjoyed during that stage. These may be taken at the full current net earnings of the company for a length of time equivalent to one-half of the educational and development period, except on roads where losses instead of profits may be fairly estimated for the development period. In the latter instances it would seem proper to consider the net losses as legitimate charges to the cost of creating the enterprise.

WORKING CAPITAL.

That working capital is absolutely necessary for the proper running of a railroad is well shown in the following extract from the opinion

of the Chairman of the Public Service Commission of New York, in the Rochester, Corning, Elmira Traction Company case:

"In addition to the foregoing matters, there should be provided upon the commencement of operation a fair and reasonable amount of working capital. The operation of the company can be continued with far greater efficiency, more to the satisfaction of the public, and with better results to the stockholders, if it has at all times in its treasury a working capital sufficient and adequate to meet the requirements of the road. Experience has demonstrated this so many times that insistence upon it or elaborate demonstration of its truth is not required at this time."

Working capital represents money permanently non-productive except through earnings derived from the transportation of passengers and freight. It includes cash held in readiness for the prompt payment of pay-rolls and vouchers, money tied up in bills receivable, and money invested in "stock on hand." The average amount may be ascertained from a study of the annual report of the railroad company.

Depreciation.

Depreciation, modified by the appreciation of those parts that improve with time, should be based on actual conditions and on suitability for continued use. As a rule, several types of depreciable and appreciable property will be found on a railroad.

Bridges, Buildings, etc.—Structures like bridges and buildings, fundamentally sound and good for an indefinite continuing life, may have their depreciation measured by the estimated expenditures required to put them in 100% condition. Generally speaking, obsolescence in such instances is believed to be too speculative for consideration.

Rails.—Certain items, like rails, are good for an indefinite continuing life, during the early stages of which there is a gradual diminishment of value followed for many years by fixed values. Rails usually pass through several stages before they are unfit for further use in track. First, they are utilized on the more important lines until their condition becomes such as to make them unfit for high-speed passenger service. Then they are transferred to lines of minor traffic, or to sidings and yards, where they may remain for an indefinite period. Manifestly, it is improper to attempt to measure their depreciation on an arbitrary mortality basis, as in some instances the character of the

traffic may be such as to wear out the rail in one-half or one-third of the assumed ultimate life, and in other cases the traffic may be so light as to permit the retention of the rail in service for possibly twice the assumed ultimate life. Therefore the depreciation of the rail in each instance must be judged by its actual condition and the kind of traffic that it bears. Commercially considered, there are three classes of rail: new, relayer, and scrap. Between the first two there is a gradually decreasing range of value from the new to the relayer price, the difference between them being spreadable over the average period during which it may be assumed that the rail will be suitable for the higher classes of service. Further depreciation below relayer value will depend entirely on actual conditions as the material approaches the point where it is removable as scrap.

Ties and Timber Trestles.—In a number of cases experience has shown that a fairly definite life may be determined. Ties, for instance, from a study of the renewal records of each company, will be found to have an average life, and the average percentage of depreciation of all the ties in track will depend on the time of year when the observations are made. Timber trestles will be found to have average lives, depending on the kind of material of which they are constructed and their location and purpose. In some instances the trestle may be made as good as new by the replacement of a few of the more perishable parts of the structure, and in other cases an entire renewal will be required. Between these limits, depreciation should be measured by the proportion of the total life of the structure that has expired.

Equipment and Machinery.—With rolling stock, floating equipment, and shop machinery and tools, obsolescence as well as decrepitude should be taken into account, as past experience has proven that there is a well-defined period of economical life beyond which continued use is wasteful or unproductive. In treating this class of depreciation, more than ordinary experience and judgment are required, because of the fact that on the character of up-keep is dependent the economical life of the item that is under consideration. Therefore it is rarely possible to adopt any fixed rule that will be applicable under all conditions.

Graduation and Ballast.—Embankments in the course of time undergo solidification following impact of rolling stock and the action of the elements. This seasoning results in appreciation that may be gauged by the estimated cost of obtaining practically the same desir-

able condition at the time of the construction of the road. This cost will depend on the availability of water for consolidating purposes, the nature and quantity of material, and the degree to which the act of solidification will interfere with the ordinary manner in which the embankments would be built.

Excavations on a new railroad are known to give much trouble from slides and filling up of ditches, entailing constant labor, often with the use of work trains, until the surfaces of the cuts adapt themselves to conditions, or, in other words, become seasoned. In the case of embankments it is possible to measure appreciation by the equivalent cost of compacting them artificially, but it is not so easy to fix definitely the value of appreciation in excavations; however, a close approximation may be made by estimating the cost of work train and other service for an assumed period of time, taking into account, of course, depths of cuts, their age, and the nature of the material.

Where slopes for fills and cuts in the course of time have become grassed or otherwise covered with vegetation which protects the surface, allowance for appreciation may be made on the basis of the cost of the adding of these items in the course of construction.

For a considerable period after tracks are first ballasted, more or less trouble and expense are involved in preserving line and surface, particularly during periods of wet and frost. This is due to the working of the ballast into the roadbed, the filling of interstices from beneath, and to the fact that the ties have not become solidly embedded in the ballast. As a consequence of these conditions, extra labor is required constantly, to readjust the track, and there is an absence of the smooth riding of trains which is so essential to fast passenger service and to the minimizing of repairs to track and equipment. As time goes on, the track is raised on new ballast, so as to maintain it at its original height, and the original ballast is pressed or settled downward into the roadbed, where it remains as a firm, semi-porous substratum or blanket to protect and sustain the overlying newer ballast. This newer ballast is the visible portion which appears above the top of the shoulders of the embankment and is usually measured and estimated as ballast. The older or concealed ballast is incorporated in the roadbed, and though it is not measured and estimated as such, its value is reflected in the appreciated worth of the part that is measured and estimated. Experiments have shown that a thickness of 24 in. beneath the bottom

of the ties is necessary to distribute the weights of rolling stock properly, and therefore appreciation of ballast may be considered as being measured by the cost of the concealed portion to a maximum depth of 24 in. below the bottom of the tie, less the cost of the roadbed material thereby replaced. Of course, if ballast is dirty and requires cleaning, the approximate cost of forking it over or otherwise cleaning it may be deducted from the appreciation arrived at as above.

Organization of Valuation Corps.

With the general principles settled which are to govern the work, the organization of the valuation corps next commands attention. Viewing the problem in the same spirit that guides the actual creation of a going railroad, it is evident that the mental attitude of the leading members of the corps must be in harmony with the practices that obtain in the inception, construction, and initial operation of the enterprise. Consequently, they must be men of broad experience in their respective fields, capable of adjusting rules and prices to conditions as they find them in each particular instance. Mere inventorying, without the detail and constant supervision of experienced engineers, will produce results which will be easily attackable in court.

In a word, the problem is one that calls for a high order of engineering skill in both rank and file, so that the outcome may reflect all the processes which have a bearing on the final cost of a live railroad.

Valuation of Road Items.—Rather than subdivide the work under a number of engineers having charge of separate subjects, such as grading, bridging, and track, the writer believes that territorial divisions or districts should be established, each in charge of an engineer capable of viewing his assigned territory as a whole, and of personally passing on the value and condition of all items in the light of their relations to each other, except those on which he will require the advice of special experts. In addition, it may be said that territorial valuation has the merit of readily lending itself to the segregation of results so that they may be made available for a variety of purposes, as, for instance, in estimating the cost per ton of transporting commodities from various originating points to destination, and in verifying values used in various taxing districts.

Although engineers with experience and ability in handling the

work as thus outlined could personally pass on the majority of the items entering into way and structures, there are several features requiring the attention of special experts.

These consist of right of way and real estate, interlocking and signals, and shop machinery and tools. In addition, the engineer in charge of each district will at times need advice on other specialties, as, for instance, heating, lighting, and power plants in shops and engine-houses, and important or unusual structures.

Valuation of Lands.—The right-of-way and real estate expert should be a man of wide experience in the purchase of land for railroad purposes, having also an intimate knowledge of railroad land values in the section in which he is located. He should be expected to ascertain the current basic values of neighboring lands as a means of measuring the value of the railroad properties, make inquiries of local real estate agents and others familiar with the subject, and, in finally fixing values, take into account the factor in each case that experience has taught should be used as a multiplier in connection with railroad purchases.

It is believed that this method of ascertaining the reproductive cost of right of way and real estate, through the central agency of one having this comprehensive knowledge of the values of land purchased and used for railroad purposes, will avoid the inconsistencies and errors which are common where the work is entrusted to a multitude of local men unversed in the broader aspects of the problem.

Valuation of Equipment.—Rolling stock and floating equipment, as defined by the Interstate Commerce Commission, should each be placed in charge of an engineer of standing in his specialty. Each locomotive, car, and boat need not be viewed personally by the appraiser, but a sufficient number of each class or type may be inspected to fix their value and condition.

Forms and Tables.—The adoption of forms on which observations are to be recorded and results compiled, is, of course, an important step in the work. The forms should be inter-connected in such a way that it will be easy to trace backward from compiled results to the parent underlying data, and they should avoid generalizations which cannot be substantiated by facts as recorded in detail on the ground.

Tables and diagrams are also of value in facilitating field and office calculation of quantities, and as a check on arithmetical work.

Conclusion.

In conclusion, it may be said that the cost of reproduction new appears to be the only measure of physical value that places all railroads on the same plane, and the only one that provides for the inclusion of every element of cost that enters into the creation of a going railroad. If properly applied, it will give due weight to the duplication of lands, under exactly the same conditions as are known to prevail in actual practice; it will provide for the inventorying and pricing of measurable items in such a manner as to recognize their correlation and the varying local conditions that surround them; it will recognize the propriety of adequate charges for overhead costs, including engineering, contingencies, general expenditures, and payments for the use of money during construction, all of which are so essential to the assemblage and endowing with life of the component parts of the system; it will take into consideration net gains or losses during the final or development stage of reproduction; and it will not forget that working capital is as necessary to the success of the enterprise as other capital charges. The fulfilling of these conditions calls for engineering skill and experience of the highest class, not alone in technical fields, but also in the broader domains of administration, finance, and operation.

A physical valuation thus embracing every item of cost that enters into the duplication of facilities in full running order, equipped, manned, and trained for the same character of service that they are now performing, may be said to include many of the intangible elements of going value which are so difficult, if not impossible, to measure in any other manner. There are, however, other elements of value, such as traffic productivity and operating effectiveness, that cannot be measured in this manner, and therefore are beyond the scope of this paper.

Whether or not physical depreciation should be deducted from the cost of reproduction new, may be said to depend on the purpose of the valuation. If its intent is the ascertainment of a price to be paid by a purchaser to whom is to be transferred the owner's liability as regards future renewals and replacements, then, beyond question, depreciation should be deducted; but, if the amount of capital invested is the point at issue, depreciation, being an element of operating cost and not a wastage of capital, should not be deducted.

AMERICAN SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

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IRRIGATION AND RIVER CONTROL IN THE COLORADO RIVER DELTA.

Discussion.*

By Messrs. R. H. Forbes and R. S. Buck.

R. H. Forbes, Esq.† (by letter).—To those who know the Colorado River, and who in a measure realize its eccentric and unmanageable character, Mr. Cory's account of control work in the Delta is rendered doubly interesting by that which the reader may find between the lines. For, in proportion as the work was difficult, original in methods adopted, and spectacular in its accomplishment, Mr. Cory's account is unassuming, matter of fact, and quietly scientific. Of the errors made by various agencies that in some way touched the reclamation of the Delta, he is most uncritical. Mr. Forbes.

An observer of events along the Colorado from 1905 to 1912 could not but be impressed by the efficiency of the Southern Pacific Railroad organization, with its ready and varied resources, its personnel, and its *esprit de corps,* in dealing with the situation. Not the least factors in a successful outcome were the democratic and friendly relations that existed between Mr. Epes Randolph, Mr. Cory, and others of the management, and the motley crew of Americans, Mexicans, and Indians whose confidence and loyal support they commanded to a remarkable degree.

Of the colossal and urgent nature of the task, the adverse weather conditions, the experimental character of the work, the conflicting advice received from influential sources, the diplomatic complications with Mexico, and the financial entanglements incident to the undertaking, Mr. Cory's own account is sufficient evidence.

* Continued from April, 1913, *Proceedings.*

† Director, Agricultural Experiment Station, Univ. of Arizona, Tucson, Ariz.

Mr. Forbes. In Dr. William P. Blake's account of the region, written shortly before his death, he relates the discovery in 1853 of San Gorgoño Pass, through which the Southern Pacific Railroad was built about twenty-five years later, and describes the descent of his party into the old lake bed, below the level of the sea.

He also outlines the topography and geology of the region, describing the lacustrine deposits, the fossils, the salt beds, the mud volcanoes, and to some extent the vegetation of the basin. He points out the manner in which the sediments of the Colorado, the tides, and rising land levels finally cut off a portion of the ancient Gulf of California, and describes the old lake Cahuilla thus formed, with its beach lines and its fluctuations in level as the river flowed to one or the other side of its delta. He even relates the Indian traditions of the former existence of this lake.

Most interesting, however, are Dr. Blake's quotations from his reports to the War Department in 1855, in which he points out the fertility of the soil, and the possibility of irrigating the region by a canal from the Colorado. He even states the danger of overflow through such a canal and the refilling of the ancient lake. The following words, quoted from the old report, have prophetic value:

"From the preceding facts [relating to soils and vegetation] it becomes evident that the alluvial soil of the Desert is capable of sustaining a vigorous vegetation." * * * "If a supply of water could be obtained for irrigation, it is probable that the greater part of the Desert could be made to yield crops of almost any kind. During the seasons of high water, or the overflows of the Colorado, there would be little difficulty in irrigating large areas in the vicinity of New River and the lagoons. By deepening the channel of New River, or cutting a canal so low that the water of the Colorado would enter at all seasons of the year, a constant supply could be furnished to the interior portions of the Desert. It is, indeed, a serious question whether a canal would not cause the overflow of a vast surface and refill, to a certain extent, the dry valley of the Ancient Lake."

Nothing is wanting here but a suggestion for the control of the river, as detailed in Mr. Cory's paper.

It is remarkable that a man in his early twenties, inexperienced in irrigation, and traveling for the first time through desert country, should have estimated so accurately the possibilities and liabilities of Salton Basin, fifty years before the development of the region. It seems that, until recently, Professor Blake's was not only the first, but the clearest, general conception of conditions in the Delta. Others have promoted the irrigation of the Basin, and some have realized the possibility of a break-way; but, until 1905, additions to knowledge of the region were mostly supplementary to Professor Blake's descriptions.

If one may look for useful suggestions in this connection, attention may be called to the necessity for a co-ordinated study, by the proper agencies, of our great physical problems, such as the utilization of a great river, and the proper control at all times of operations affecting the final solution of such a problem. The "pork-barrel" method of handling river improvements from the governmental side, is admittedly desultory and wasteful; and it is to be feared that scientific agencies engaged in the study of these same problems, as a rule, are not well co-ordinated. It may be that the Colorado has drawn attention to these facts, with corresponding advantages to come. The Newlands River Regulation Bill, now before Congress, will make possible a comprehensive study and development of the Colorado River as a whole, for storage, power, and irrigation; and the Carnegie Institution, on the purely scientific side, is soon to publish a collection of scientific papers relating to the Delta region, among which will appear Professor Blake's complete paper. Mr. Forbes.

R. S. Buck, M. Am. Soc. C. E. (by letter).—The writer has read Mr. Cory's paper, as well as several of the discussions thereon, with great interest, but is forced to a view radically different from that of Mr. Sellew regarding the propriety or advisability of incorporating in such an engineering paper so much collateral matter of legal, financial, and (he might have added) political character. Mr. Buck.

Mr. Sellew says:

"The record of the operations incident to the return of the river to its former channel is extremely complete, although partly obscured by a mass of legal and financial entanglements which properly have no place in a purely engineering article."

While it may have necessarily taken a longer time in the relating than the casual reader, in quest of purely technical knowledge, may have desired, one of the principal features of interest and value to the writer in Mr. Cory's paper is the graphic portrayal of the desperate odds which engineering talent and effort are often forced to meet, as a result of long-range financial management, clogging legal complications, and the blind, selfish play of the political game.

Engineering work is now controlled by forces far beyond the laws of physics, and, if he would occupy a position to which his technical talents properly entitle him, the engineer must learn something of these forces.

In the writer's opinion, Mr. Cory is to be commended rather than criticised for devoting so much attention to the conditions in question, for he has certainly thrown light on some dark places, and has shown how vital it is for engineers to consider, in their planning, the laws and habits of men and money, as well as the laws of Nature.

Mr. Buck. The Lower Colorado is not merely a problem of yesterday, presenting a vague general moral. It is a vital problem of to-day and to-morrow and of years to come. It will probably take a place alongside the Lower Mississippi River as another engineering problem, dragging out a long, weary, and costly existence as a result of Government incompetence and political selfishness.

Of course, Mr. Cory's paper can affect but little the thus far meager results of mighty efforts to control the Colorado, but it should have a marked effect on future efforts, if a reasonable amount of intelligence is to direct these efforts.

If Mr. Sellew's apparent views were shared by the Publication Committee, we would have no papers such as those on water laws and valuation of public utilities. The importance of these and similar collateral subjects, the writer feels, is growing to be more and more appreciated from the engineering point of view.

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THE INFILTRATION OF GROUND-WATER INTO SEWERS.

Discussion.*

By Messrs. E. G. Bradbury and Marshall R. Pugh.

E. G. Bradbury, M. Am. Soc. C. E. (by letter).—A sewer which does not carry a much larger flow during heavy rains than in dry weather is an exception, and, as the maximum flow must be provided for in the design, it is important that information regarding leakage should state the weather conditions. Probably most of the data on systems in use are based on the difference between the storm flow and that of dry periods. There is danger, however, of obtaining misleading figures from observations of leakage in new sewers, or in sewers without connections, when the ground-water is comparatively low, for they may show nothing more than the quantity of water which can make its way through the soil to the sewer. This should be borne in mind in comparing gaugings of leakage in the same sewer at different dates. Mr. Bradbury.

Under average conditions, few sewers are built which fail to permit the entrance of ground-water as fast as it can get to them, except during a heavy rain. This is demonstrated by the fact that water is seldom encountered in making connections to public sewers; it is also shown by the usual great increase of leakage coincident with storm conditions.

Unless the tightness of the work, rather than the imperviousness of the soil, is the controlling factor in the quantity of leakage, the size of the sewer evidently makes no difference. As this is seldom the case, it is not strange that there has been great difficulty in establishing any relation between diameter and leakage.

* Continued from March, 1913, *Proceedings*.

Mr. Bradbury.

The writer has become convinced, much against his will, that, in the average location, with the ordinary method of making cement joints in pipe sewers, even with the most thorough supervision and careful inspection, the ground-water level immediately along the line of the sewer is invariably lowered to the level of the pipe, sloping upward from it at a gradient depending on the porosity of the soil, the surface topography, and other conditions. Under these circumstances, the original height of the ground-water enters into the problem of leakage only as it affects the flow toward the sewer.

It is seldom possible to determine without great effort the actual head on a sewer under working conditions. The writer believes that if data were limited to observations in time of heavy storm, when the tightness of the sewer is really put to test, something more remotely suggestive of a relation between size and leakage than has yet been produced, might result, although the surreptitious connection of roof drains, the inflow at manholes, and other possible means for the entrance of surface water, render this one of the most difficult subjects on which to obtain reliable information.

In the consideration of disposal plant design, it is necessary to have in mind both the ordinary infiltration, which is a function of soil and ground-water conditions, and the leakage in time of storm, which is governed more directly by the tightness of the construction. The one will cause a continuous flow, usually of small consequence, and the other an occasional heavy discharge which may overtax the capacity of piping, weirs, etc., and perhaps derange seriously the operation of tanks and filters. If the writer's views are correct, it is of course entirely fruitless to attempt to reduce normal infiltration to terms of diameter of pipe; but it should be possible, as already suggested, to establish some general relation which would be of value in estimating the maximum leakage during storm periods.

Mr. Pugh.

Marshall R. Pugh, M. Am. Soc. C. E. (by letter.)—The information contributed as a result of this timely paper is most interesting; and, in the hope that it may give the author material which will be of use in his closing discussion, the writer submits some observations made by him recently at Ocean Grove, N. J. South of Asbury Park is Neptune Township, the eastern part of which, known as Ocean Grove, is owned by the Camp Meeting Association. West of this are West Grove and Bradley Park, the greater part of which are included in what is known as "Sewer District No. 1." About a year after the construction of the sewerage system, the writer was retained to design sewage disposal works. The infiltration was so important a factor that a number of observations were made in the effort to determine it, and though the results are discordant in one or two particulars, it is thought that this is due chiefly to the impossibility of determining

accurately the sewage flow as distinguished from the infiltration flow, other than by an estimate based on the houses sewered; there is also the great probability that one portion of the system is badly blocked up by sand, as will be noted later. Mr. Pugh.

The system is divided into two parts, joining at a pumping station, which is being supplanted by a gravity outfall now under construction. The lengths and sizes of the sewers are shown in Table 8.

TABLE 8.

Item.	Length of north section, in feet.	Length of south section, in feet.	Length of entire system, in feet.	Remarks.
12-in. terra cotta sewer .	1 525	3 400	4 925	System built, 1909-1911.
10 in. " " " .	......	1 000	1 000	Pipe in 3-ft. lengths,
8 in. " " " .	13 325	23 460	36 785	with cement joints.
4 in. laterals............	2 300	5 140	7 440	Two laterals or Y 's
Total pipe................	17 150	33 000	50 150	every 50 ft. Soil wet,
Brick manholes..........	36	72	108	sandy loam.

It will be noted that the number of linear feet of joint in the total length of the 4, 10, and 12-in. pipes, in both the north and south sections of the system, corresponds so closely to the number of linear feet of joint in an equal length of 8-in. pipe, that, for all practical purposes, the system may be considered as consisting of the following:

North section................ 3.25 miles of 8-in. pipe.
South section................ 6.25 " " " "
Entire system................ 9.50 " " " "

The sewers are laid in a soil consisting partly of sandy loam and partly of sandy clay, or clayey sand, underlaid by gravel, and at times there may be a head of from 3 to 5 ft. of water on the pipes at the lower end of the system, and from 1 to 2 ft. at the upper end. The pipes are in 3-ft. lengths, with the ordinary cement joint, and have a slant or lateral on each side about every 50 ft. They were probably laid with only very ordinary care, and about 76 of the manholes were not brought quite up to street grade, being from 4 to 12 in. too low, and 9 of them still have temporary wooden covers. Some of the manholes were very leaky, and two of them had powerful jets of water shooting through the sides.

As nearly as could be ascertained, the infiltration at times was approximately 900 000 gal. per day, and the house sewage, with the few connections as yet made to the system, amounts to about 50 000 gal. per day, divided fairly equally between the two sections. A sewage ejector which was placed at the pumping station has been discontinued, and, during construction, a temporary pumping plant has been

Mr. Pugh. erected. From the records of this plant the following details have been obtained. The rainfall data are given in Table 9, and show what an all-important factor is the precipitation.

TABLE 9.—MONTHLY AVERAGES OF PRECIPITATION.

Month. 1912.	Total, in inches.	Greatest in 24 hours, in inches.	Total snow fall unmelted, in inches.
April	4.41	1.06	....
May	6.47	3.21	....
June	1.12	0.70	....
July	4.33	2.53	....
August	3.04	1.46	....
September	3.46	1.42	....
October	6.95	3.12	....
November	3.82	2.27	....
December	5.49	1.94	11.2

Table 10 shows the infiltration in the entire system, in a dry time, before any attempt had been made to diminish the ground-water flow into the pipes.

TABLE 10.—INFILTRATION IN ENTIRE SYSTEM BEFORE REPAIRS, AND IN A DRY PERIOD.

Date. 1912.	Precipitation, in inches.	Hours of pumping.	Gallons pumped per day.	Approximate infiltration, in gallons per day.	Infiltration, in gallons per day per mile of sewer.	Infiltration, in gallons per day per inch diameter of pipe per mile of sewer.
July 20	....	7	112 000	62 000	6 526	816
21	1.21	8.30	136 000	86 000	9 052	1 131
22	....	17	272 000	222 000	23 368	2 921
23	....	14.40	235 000	185 000	19 473	2 434
24	....	10.30	168 000	118 000	12 421	1 552
25	....	7	112 000	62 000	6 526	816
26	....	8	128 000	78 000	8 210	1 028
27	....	8.30	136 000	86 000	9 052	1 131
28	0.05	8.30	136 000	86 000	9 052	1 131
29	0.01	8	128 000	78 000	8 210	1 028
30	....	8	128 000	78 000	8 210	1 028
31	Trace.	8.15	132 000	82 000	8 632	1 079

Table 11 shows the results after the tops of 76 manholes had been raised, and the leaky ones had been made tight.

At the time the repairs were made, the south section was disconnected, and Table 12 gives the infiltration in the north section alone.

The much higher infiltration per mile in the north section may be due to the fact that a large part of the south section is in territory which is not built up, and there is reason to believe that a great many stoppages are caused by sand which is washed in at the manholes (the

tops of 50 being below the grade of the streets), thus blocking off the escape of the ground-water through the sewers. Mr. Pugh.

Then, too, the outlet of the north section is about 2 ft. lower than that of the south section, and is under a greater head of water. A part of the north section, also, runs through filled-in land which was formerly a swamp.

TABLE 11.—INFILTRATION IN ENTIRE SYSTEM AFTER REPAIRS, AND IN A DRY PERIOD.

Date 1912.	Precipitation, in inches.	Hours of pumping.	Gallons pumped per day.	Approximate infiltration, in gallons per day.	Infiltration, in gallons per day per mile of sewer.	Infiltration, in gallons per day per inch diameter of pipe per mile of sewer.
Sept. 20..	0.01	4.35	73 300	23 300	2 452	306
21..	....	5	80 000	30 000	3 158	395
22..	....	5.20	85 300	35 000	3 684	460
23..	Trace.	5.10	82 650	32 000	3 368	421
24..	0.76	6.50	109 300	59 300	6 242	780
25..	1.42	7.10	114 600	64 600	6 800	850
26..	....	7.30	120 000	70 000	7 368	921
27..	Trace.	6.20	101 300	51 300	5 400	675
Oct. 7	No rain in October prior to this.	5.55	94 700	44 700	4 705	588

It will be noted that the infiltration shown in Table 12 was for a somewhat drier time than that in Table 11.

TABLE 12.—INFILTRATION IN NORTH SECTION AFTER REPAIRS, AND IN A DRY PERIOD.

Date. 1912.	Precipitation, in inches.	Hours of pumping.	Gallons pumped.	Approximate infiltration, in gallons per day.	Infiltration, in gallons per day per mile of sewer.	Infiltration, in gallons per day per inch diameter of pipe per mile of sewer.
Oct. 8	....	4.45	72 000	47 000	14 461	1 808
9......	....	4.40	74 600	49 600	15 261	1 907
10	....	4.45	72 000	47 000	14 461	1 808
11.....	0.76	5.0	80 000	55 000	16 930	2 116
12.....	0.01	4.40	74 600	49 600	15 261	1 907
13......	...	4.30	73 300	48 300	14 861	1 857
14	....	4.40	74 600	49 600	15 261	1 907
15	....	4.45	72 000	47 000	14 461	1 808

It is obvious that there cannot be more infiltration in the north section than in the entire system; which shows that the estimated sewage flow is open to suspicion, and, in all likelihood, is not properly proportioned between the two sections. The fact that the total pump-

Mr. Pugh.

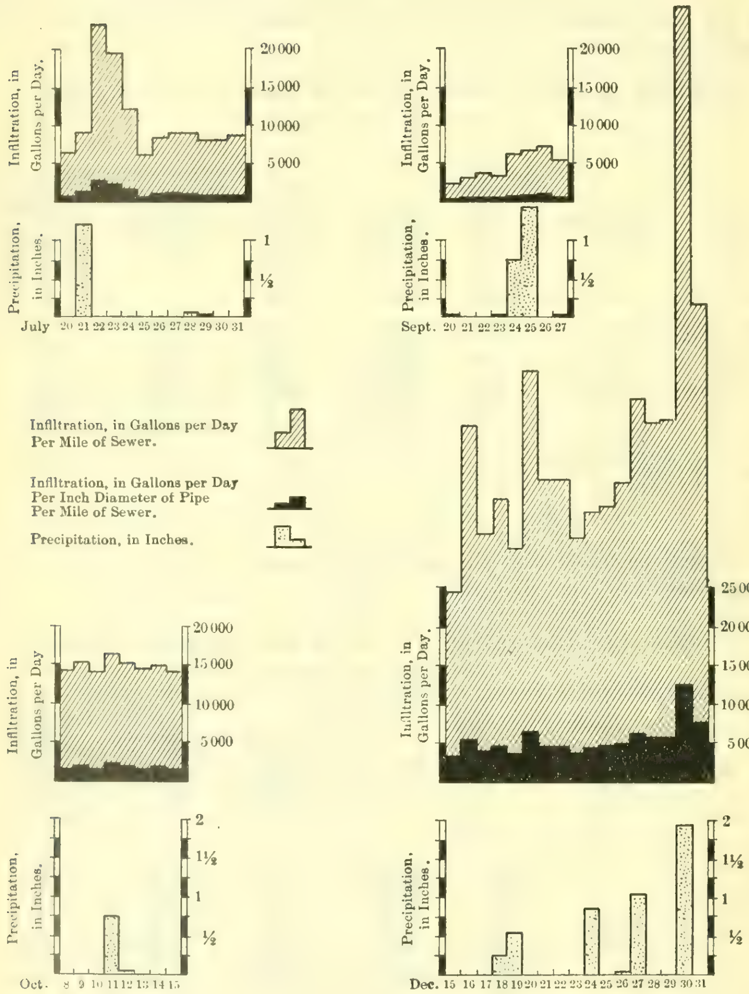
Infiltration, in Gallons per Day.
20 000
15 000
10 000
5 000
Precipitation, in Inches.
1
½
July 20 21 22 23 24 25 26 27 28 29 30 31
Sept. 20 21 22 23 24 25 26 27
Infiltration, in Gallons per Day Per Mile of Sewer.
Infiltration, in Gallons per Day Per Inch Diameter of Pipe Per Mile of Sewer.
Precipitation, in Inches.
25 000
2
1½
Oct. 8 9 10 11 12 13 14 15
Dec. 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

FIG. 2.

age only fell off from 94 700 to 72 000 when two-thirds of the system was cut out, showed, however, the general correctness of the higher infiltration figures in the north section. Mr. Pugh.

The latter part of October was wet, and the flows shown in Table 13 clearly demonstrate the effect of the rise in the ground-water in winter.

TABLE 13.—Infiltration in North Section After Repairs.

Winter Conditions.

Date. 1912.	Precipitation, in inches.	Hours of pumping.	Gallons pumped.	Approximate infiltration, in gallons per day.	Infiltration, in gallons per day per mile of sewer.	Infiltration, in gallons per day per inch diameter of pipe per mile of sewer.
Dec. 15...	....	6.30	104 000	79 000	24 308	3 038
" 16...	....	11.	176 000	151 000	46 461	5 808
" 17...	....	8.10	130 600	105 600	32 492	4 061
" 18...	0.26	9.	144 000	119 000	36 615	4 577
" 19...	0.57	7.30	120 000	95 000	29 230	3 654
" 20...	....	12.25	198 600	173 600	53 414	6 676
" 21...	....	9.30	152 000	127 000	39 077	4 760
" 22...	....	9.30	152 000	127 000	39 077	4 760
" 23...	....	8.	128 000	103 000	31 600	3 950
" 24...	0.86	8.40	138 600	113 600	34 900	4 362
" 25...	....	8.45	140 000	115 000	35 300	4 412
" 26...	Trace.	9.25	150 600	125 600	38 600	4 825
" 27...	1.05	11.35	185 300	160 300	49 300	6 162
" 28...	....	11.	176 000	151 000	46 400	5 800
" 29...	....	11.05	177 300	152 300	46 800	5 850
" 30...	1.94	22.	352 000	327 000	100 615	12 577
" 31...	....	16.	256 000	201 000	61 800	7 725

At first sight it appears strange that the 0.86 in. of precipitation on December 24th did not show in the sewer flow, but it is easily accounted for, as it consisted of a 10-in. fall of snow, on frozen ground, followed on the 27th by a cold rain, which increased the flow somewhat. On the 29th there was a thaw, and a heavy downpour on the 30th, the result being at once visible. The cause of the increase on December 16th is difficult to explain.

Fig. 2 shows graphically the precipitation, and the infiltration, in gallons per day per mile of sewer, and in gallons per day per inch of diameter of pipe per mile of sewer.

These units appeal to the writer as the most convenient and satisfactory for general use, although the latter is open to the serious objection that manholes, slants, and laterals are frequently as numerous on the smaller sewers as on the larger ones, and they undoubtedly are responsible for much leakage.

AMERICAN SOCIETY OF CIVIL ENGINEERS

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PAPERS AND DISCUSSIONS

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A SUGGESTED IMPROVEMENT IN BUILDING WATER-BOUND MACADAM ROADS.

Discussion.*

BY MESSRS. ARTHUR H. BLANCHARD AND J. L. MEEM.†

ARTHUR H. BLANCHARD, M. AM. SOC. C. E.—Two properties of wearing surfaces which require consideration in the design of pavements are stability and density. The requisite degree of stability and density depends in part on the conditions to which the road or pavement is to be subjected. The author has outlined a method for securing a certain degree of stability and density in the construction of the so-called water-bound macadam road. Mr. Blanchard.

The efficacy of the proposed method depends primarily on the traffic to which the road is to be subjected. If the traffic consists of horse-drawn vehicles not exceeding a certain number per day, the use of the type of construction advocated should result in a serviceable road. If, however, many high-speed motor cars use the highway thus built, the surface will disintegrate rapidly, as is the case with macadam roads built with a wearing surface of so-called crusher-run stone (passing over a ½-in. screen and through a 1½-in. screen), the surface of which is finished with a light coat of screenings, well rolled and watered. The difference between the former and the latter is in the arrangement of the aggregate, rather than in its composition, as is seen by a consideration of the following mechanical analysis of the wearing surface of the latter type.

Broken stone passing	⅛-in. screen.......	1.0 per cent.
" " "	¼ " "	2.5 " "
" " "	½ " "	30.8 " "
" " "	¾ " "	34.2 " "
" " "	1 " "	23.4 " "
" " "	1¼ " "	8.1 " "

* Continued from April, 1913, *Proceedings*.

† Author's closure.

Mr. Blanchard.

The analysis of the author's wearing surface of 2 in. would likewise show certain percentages passing screens from $\frac{1}{4}$ in. to $1\frac{1}{4}$ in. In both cases, stone from $\frac{1}{2}$ in. to $1\frac{1}{4}$ in. in diameter will usually constitute a large percentage of the top inch of the surface.

The speaker's investigations and practice have led to the conclusion that the most satisfactory type of macadam road to withstand high-speed motor-car traffic is one having a surface of broken stone, varying from 1 in. to $2\frac{1}{2}$ in. in longest dimensions, which stone has been thoroughly rolled and puddled. The success attendant on the use of bituminous surfaces on macadam roads in England and France is due in part to the adoption of this type of construction. Not only does the use of the large broken stone in the surface give stability to its component integral parts, but it simplifies one essential detail of the construction of bituminous surfaces on macadam roads, namely, the cleaning of the macadam surface.

With the addition of bituminous cement, the status of the pavement, as one adaptable for use on highways subjected to motor-car traffic, is changed. The method of construction in which several courses of varying sizes of stone are used formed the basis of many of the patents covering the construction of bituminous concrete pavements granted by the United States Government during the period from 1869 to 1873. Bituminous concrete pavements of this type have given excellent results, in the United States and also abroad. At present, several foreign companies, particularly in England, are using this method of construction. The work of three of these companies is referred to in the following descriptions:

The Quarrite-Bitulithic Company of London imports from its Scotland plant bituminous-coated broken stone of various sizes for the construction of bituminous concrete pavements by the layer method. The sizes used for the courses are as follows: first course, 2 in. of 1-in. to $1\frac{3}{4}$-in. stone, rolled, with a scattering of $\frac{1}{8}$ to $\frac{3}{8}$-in. chips; second course, 1 in. of stone, varying from $\frac{1}{4}$ to $\frac{3}{4}$ in. in longest dimensions, rolled; third course, a thin layer of tar-coated screenings, thoroughly rolled.

The Tarmac Company of London for many years has been mixing broken slag of various sizes with bituminous cement at its plant in Wolverhampton, and shipping from there to various points in England. The construction of one pavement of this type which came under the speaker's observation is as follows: This road was the main shore boulevard at Brighton-on-Sea, on the south coast of England. On a well-compacted gravel foundation was spread a scattering of bituminous-coated chips; the bottom layer, composed of $3\frac{1}{2}$ in. (loose) of $1\frac{1}{4}$ to $2\frac{1}{2}$-in. slag, was then rolled; the second course, consisting of $2\frac{1}{2}$ in. (loose) of $\frac{1}{2}$-in. to $1\frac{1}{4}$-in. slag, was next thoroughly compacted; the

third course, composed of ½ in. of ¼ to ½-in. slag chips, was likewise thoroughly rolled; the pavement was finished by rolling in a top dressing of uncoated slag screenings. It may be of interest to note that a section on Madeira Drive, at this famous shore resort, was constructed in this manner in 1903. Its condition in 1910 was excellent, and an adjoining section of water-bound macadam, which was treated annually with an application of tar, rapidly disintegrated before the close of each season. Mr. Blanchard

As an illustration of the practice in Germany, the work of the Deutsche Quarrite and Bitulithic-Pflaster-Gesellschaft of Berlin may be cited. In 1910 this company built a bituminous concrete pavement in Lankwitz, Germany, in accordance with the following method: On a 5-in. macadam cinder-filled foundation, the first course, consisting of 4 in. (loose) of 1½-in. stone, was spread and rolled; a thin coat of tarred chips was next spread and rolled; the second course consisted of 1 in. of ¾-in. stone, well rolled; the final course was ½ in. of tarred chips, also thoroughly rolled; the pavement was finished with a flush coat of tar, on top of which was spread uncoated screenings.

That the layer method of constructing bituminous concrete pavements in England is not of recent date is shown by the following description published in 1898:

"The hot stone, when ready for mixing, is screened into material of three sizes, 1 to 2-in. for the body, ½ to 1-in. for the intermediate coat, and ¼ to ½-in. for the top dressing. The coarsest material is used in a layer from 3 to 4 in. thick, the intermediate size forms a coat of about ¾ in., and the top dressing is used in the thinnest layer possible, with a view to filling all interstices. Afterward a dressing of ¼-in. and smaller granite screenings is scattered broadcast, and the traffic is at once allowed on the road to work this top dressing into the tarred material. Each of the layers is rolled separately with a 10-ton roller."

In conclusion, the opinion is expressed that, provided a bituminous cement is mixed with the stone for the second and third courses, the use of the principles of construction embodied in this interesting paper will produce a pavement which, under conditions for which it is suitable, will be economical in construction and maintenance.

J. L. Meem, Assoc. M. Am. Soc. C. E. (by letter).—In reply to Mr. Frink the writer wishes to state that his method deals primarily with the manner of placing the different grades of stone, assuming that the sub-grade is in proper condition to receive them. He agrees with Mr. Frink that the preparation of the sub-grade, drainage, etc., are prime factors in the life of the road, but these are conditions to be controlled locally by the engineer in charge. Mr. J. L. Meem.

The writer is pleased to note that Mr. Sweetser has tried and obtained good results by this method of separating the dust from the

Mr. J. L. Meem.

screenings and applying them in separate layers. Mr. Sweetser says, in reference to building a road which will be affected less by automobile traffic: "Why not construct at once, so that it will not be affected at all?" The writer is not a champion of "water-bound macadam" roads, and realizes that it is the least durable form of stone pavement; but, as it is the generally accepted form of highway improvement, as adopted by the various counties, due to low first cost, he believes that any improvement in this method of construction without additional cost will be welcomed.

The writer feels that Mr. Crosby's failure to obtain good results by this method of proportioning the rock was due to the fact that he allowed a portion of the chips ($\frac{1}{4}$ to $\frac{1}{2}$ in. in size) to be taken for other purposes, thereby failing to fill the voids in the No. 2 stone. A section of roadway built with the foregoing proportions of rock shows practically a solid mass.

Mr. J. C. Meem's suggestion, that a frequent sprinkling or application of oil as a dust preventive would prolong the life of the road, is a good one. This would be of great benefit, especially during long dry periods, but having done this, we have departed from the true water-bound macadam, and Mr. Sweetser's query "Why not construct a permanent road?" presents itself.

Mr. Blanchard's interesting discussion applies to bituminous macadam rather than to water-bound macadam, as set forth in the paper.

The writer is pleased to have obtained the views of others on this simple little change in an accepted specification, and hopes it will at least have the effect of causing others to try the change.

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PAPERS AND DISCUSSIONS

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ON LONG-TIME TESTS OF PORTLAND CEMENT.

Discussion.*

By George S. Binckley, M. Am. Soc. C. E.

George S. Binckley, M. Am. Soc. C. E. (by letter).—In providing a stimulating center of discussion, Mr. Hiroi's brief paper on long-time tests of cement is particularly valuable. Such data as those he presents are certainly of high importance, and the curves given by Mr. Davis,† Figs. 4 and 5, are still more suggestive, especially in consideration of the conditions under which these really startling results have been obtained. Mr. Binckley.

These two sets of curves present such a striking contrast between the American and foreign cements as to call for more than passing comment. They are of peculiar interest to the writer in tending to strengthen a growing suspicion that American cements lack the inherent soundness found in the best of those of foreign manufacture.

Some years ago, the writer had occasion to make a comparison between one of the best-known of the English Portland cements and a cement made in Western Canada, and in the course of these tests some very curious and suggestive results were obtained. So striking were some of these that the writer used them as the basis for a brief article published soon afterward.‡ In few words, these particular tests had to do with the qualities of the coarser particles in Portland cement—those passing the 100-mesh and remaining on the 200-mesh screen.

In the cements examined, this material, contrary to the commonly accepted idea, showed very considerable hydraulic properties; in fact, briquettes gave a tensile strength at 7 days of 126 lb. for the Canadian, and 220 lb. for the English briquettes; at 28 days the

* Continued from March, 1913, *Proceedings*.

† *Proceedings*, Am. Soc. C. E., for March, 1913.

‡ *Engineering Record*, Feb. 19th, 1910, p. 212.

Mr. Binckley. figures were 215 lb. for the Canadian and 353 lb. for the English briquettes. Mr. Spackman, of Philadelphia, has suggested to the writer that part of this effect was due to fine particles adhering to the coarser ones, yet he admits a certain hydraulicity in at least the superficial part of the coarse particles themselves.

Both these cements passed the standard tests successfully, the gain in strength between 7 and 28 days being 90 lb. in each. Both cements, neat, stood the accelerated tests successfully; and the Canadian cement showed a greater strength than the English at both 7 and 28 days.

When the briquettes or pats made from this intermediate material—that passing the 100-mesh and remaining on the 200-mesh screen—were subjected to the steam test under atmospheric pressure, however, the difference in results was startling. The accompanying photographs of these test pats and briquettes (Figs. 7 and 8) make this very clear. The English pat and broken briquette remained perfectly hard and sound, and those made from the intermediate material of the Canadian cement quickly broke down. To quote from the article previously referred to:

"Standard boiling pats were prepared and placed on the same glass plate to secure perfect identity of conditions. On account of the crumbling (noted above) of the edges of the briquettes made from the intermediate material screened out of the Canadian cement, these boiling pats were kept in moist air 60 hours before boiling to insure a perfectly fair test.

"The two pats representing the two cements investigated were then placed in cold water, which was raised to the boiling point. Boiling was continued for 2½ hours, at the end of which time the condition of the two pats may be seen by reference to the accompanying photograph. That pat made from the intermediate material of the English cement showed no deterioration whatever, adhered tightly to the glass, and was free from any sign of cracking. It in every respect indicated perfect soundness. The other pat, made from intermediate material screened out of the sample of Canadian cement, showed the first sign of breaking down 45 minutes after being placed in the water, and its integrity was completely destroyed in two hours and a half. Its condition is most graphically shown in the accompanying photograph, in which it is seen that it is cracked and disintegrated to such an extent that its interior is in a granular or sandy condition.

"These results were so striking that a further boiling experiment was made on half of one of the briquettes, the 28-day [Canadian] specimen showing a tensile strength of 215 lb. per square inch. * * * This briquette was boiled when it was 38 days old. Yet in spite of its comparatively high strength and thorough seasoning in and out of water, it broke down completely after about five hours' boiling, as shown in the photograph.

"This complete failure was a surprise, as there had been no visible sign of deterioration before boiling; yet but a short time after the water had reached the boiling point the first sign of distress appeared."

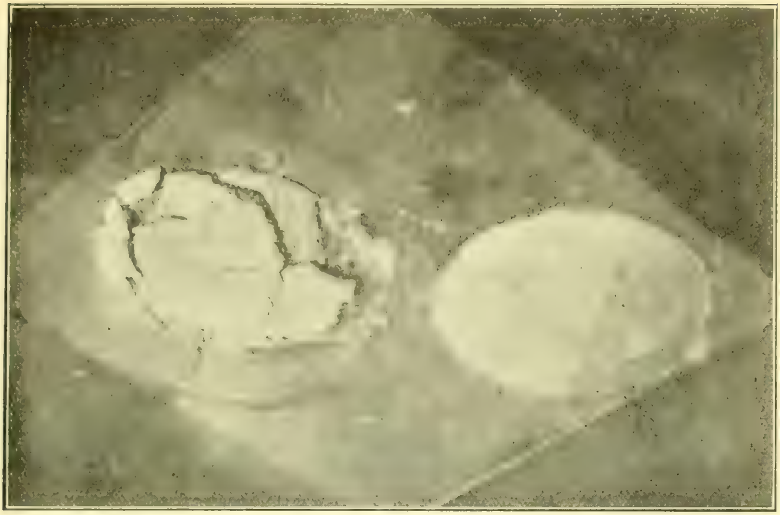

FIG. 7.—"PATS OF INTERMEDIATE MATERIAL AFTER BOILING."

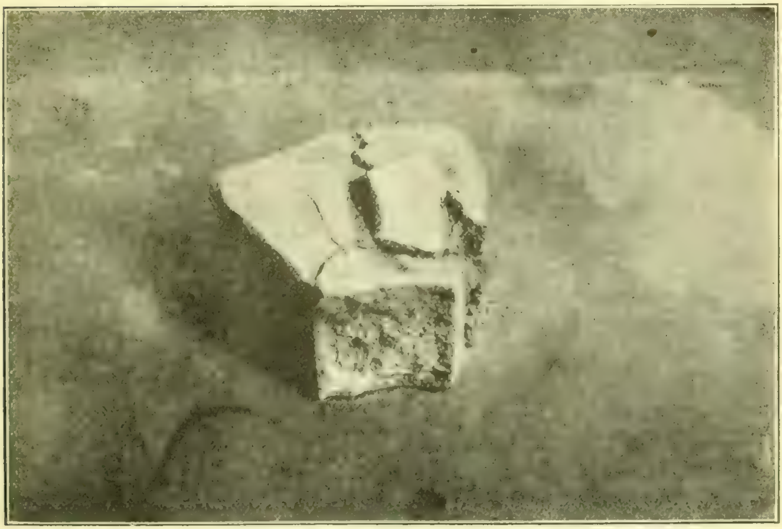

FIG. 8.—"BRIQUETTE OF INTERMEDIATE MATERIAL."

The writer considered these results highly suggestive. Here are two cements, each apparently conforming to the standard tests for soundness; yet, when one is subjected to the writer's test, it is seen to contain an element of weakness, and the other remains sound. The Canadian cement seems to contain about 20% by weight of a material inherently mischievous, but protected in such a way, under the standard tests, as to remain undiscovered. In other words, this Canadian cement—and probably a great many American cements also—contains in its coarser particles an element of weakness which evades discovery under the standard tests, but may reasonably be expected to reveal itself as the years pass. This is strikingly indicated in Mr. Davis' curves, and, in the case of neat cements, in the curves presented by Mr. Honness (Fig. 6)* and also, to a less striking yet notable degree, in Mr. Hiroi's paper. Mr. Binckley

Though it would hardly be proper to consider the characteristics of American cements as indicated by these data as a cause of actual alarm, they can hardly be considered satisfactory. Even qualified and at least partly compensated by the better showing made by the sand briquettes, Mr. Davis shows curves representing an average of eight brands of American cement that lead one to wonder where the rapid drop in strength will stop, if at all. It must be remembered, also, that those eight brands probably represent the best cements obtainable for the works considered, as it is incredible that inferior or suspected cements would be placed under a long-time test and allowed to drag down a good average. The curve Mr. Davis gives for a single brand in 1:3 sand briquettes is rather appalling, for it has lost 50% in 4 years, and is still falling off.

The engineer cannot afford to contemplate with composure the possibility of a progressive deterioration of a supposedly permanent material of such importance. If cement is to fall under the head of materials subject to deterioration, the sooner we know it the better, to the end that its life may be calculated, replacements provided for, and means taken to prevent disastrous failures. If, on the other hand, we are to have a dependable material for all the ages, which, built into our structures will actually—as so confidently assumed—improve in strength with the years, defects must be sought out, and faulty material must be rejected without mercy. In the article previously referred to, the writer suggested the advisability of applying the test described as a ready means for the detection of inherent weakness in a cement passing the standard tests. Since that time, a still more drastic test—the autoclave test—has been advocated, but this requires special and rather costly apparatus, and is so drastic that it seems probable that few American cements would succeed in passing

* *Proceedings*, Am. Soc. C. E., for March, 1913.

Mr. Binckley.

it. Yet the writer believes that the time will come very soon when engineers will find it prudent or even imperative to subject the cement required for works of importance to far more searching tests than those now in use; and if the cement manufacturers find it difficult or even impossible to supply cement of the required integrity under their present methods of manufacture, they will simply have to improve their methods. As soon as the certainty of eventual weakness in concrete made with any particular class of cement is established, or even a strong suspicion of concrete as a permanent material is aroused, some very strict requirements will have to be met by the cement manufacturers.

In the meantime, the writer suggests—even urges in cases of importance—the application of the tensile and steam tests to that part of the material passing the 100-mesh and remaining on the 200-mesh screen. This material should be made into standard boiling pats and briquettes, and carefully observed. Everything else being apparently equal, as between rival cements, this test will certainly give a definite indication of relative soundness that should fix one as superior.

AMERICAN SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

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CONSTRUCTION PROBLEMS, DUMBARTON BRIDGE, CENTRAL CALIFORNIA RAILWAY.

Discussion.*

By Messrs. O. E. Hovey and Lewis D. Rights.

O. E. Hovey, M. Am. Soc. C. E.—The speaker has been much interested in this concise and well illustrated paper; and, though there are many interesting details in the draw-bridge superstructure which might be mentioned if any extended discussion of it was undertaken, only a few points which were of particular interest to him during the design of the draw span, early in 1907, will be mentioned. The Dumbarton draw span was one of the heaviest center-bearing spans which had come to the speaker's notice at the time the design was made. The center-bearing type of draw was considered to be particularly desirable in this location on account of the difficulty in securing foundations, the simpler details of the center, the rigidity of the bridge under traffic after the wedges at its ends and center were driven home, and the ease with which final adjustments of height of center and end supports could be made during construction in case there was any settlement of the piers. The center bearing of this bridge was designed for a total load of about 2 600 000 lb. Grillages of I-beams were embedded in the concrete of the end and center piers, under the end and center wedge supports and the center pivot. The center pivot casting rested directly on the top of the center grillage, and the disks at the top of this casting consisted of two steel plano-concave and one phosphor-bronze double convex disks, 36 in. in diameter. These disks were the largest with which the speaker was familiar at the time the design was made, although much larger ones have been used more recently in the manufacture of draw bridges, the largest with which the speaker is familiar being those supporting the Mr. Hovey.

* Continued from April, 1913, *Proceedings*.

Mr. Hovey. Southern Pacific draw span over the Sacramento River, at Sacramento, Cal., which are 52 in. in diameter.

The design of the power plant in the operator's house of the Dumbarton draw is of interest because, although it was expected ultimately to use electric energy for operating the draw, electric current would not be available at the time the bridge was completed, and it was necessary, therefore, to provide some other source of power temporarily, and desirable to have an alternate power available, even after the electric current was in use. For the permanent equipment a 52-h.p. motor, designed to use 440-volt alternating current, was provided. For temporary and alternative use an 80-h.p., three-cylinder, four-cycle, gasoline engine, running at about 300 rev. per min., was selected. In the operation of this draw bridge it is necessary to provide, from one source of energy, means to lower and raise the center end and wedges, and also to open and close the bridge itself, four separate operations being required. The type of gasoline engine selected was not reversible, therefore special transmission mechanism was necessary to produce rotations in each direction for lowering and raising the ends of the bridge and for opening and closing the main structure. Many bridges have been built with mechanism to provide for these four motions, but, in a large number of cases, the necessary shafts, gears, clutches, levers, etc., have been located in various positions on the superstructure. In conformity with the well-established practice of the builders of this bridge, it was decided to use a type of transmission mechanism, between the gasoline engine and the main shafts of the bridge, which would be entirely within the operator's house and self-contained on a large cast-iron bed-plate, so that the transmission mechanism could be assembled and carefully aligned in the shop and then shipped to the bridge in such condition that a minimum of field work would be necessary in placing and adjusting it. This transmission mechanism included two mechanical and two friction clutches, with the necessary shafts, gears, and friction-band brake control, all actuated by the operator from a central point.

The electric motor selected was of the ordinary reversible type, and therefore required special transmission mechanism to shift the application of power to the wedge-operating shafts or bridge-turning shafts at pleasure; but it did not require special mechanical provision for reversing the direction of rotation. To keep the whole mechanism compact and rigid, it was decided to place the motor on a cast-iron base which was carefully fitted and bolted against one end of the cast-iron base of the gasoline engine transmission mechanism. The motor base also supported bearings for a countershaft, the pinion of which was arranged to mesh directly with a gear on the extended end of a countershaft of the gasoline engine transmission mechanism. The motor countershaft was also provided with a friction cut-off coupling,

so that by moving a hand-lever the motor could be thrown into engagement with the gasoline engine transmission mechanism or allowed to run idle. By this construction, it will be noted, the transmission mechanism can be driven by the gasoline engine or by the electric motor, at pleasure, and in case of necessity a shift from electric power to gasoline engine power can be made simply by releasing a clutch and starting the gasoline engine. Mr. Hovey.

On account of the location and weight of the bridge, the time of opening and closing was fixed at 2 min., as stated in the paper. During a visit to the Pacific Coast in July, 1912, the speaker had an opportunity to inspect the Dumbarton Draw Bridge, and during this inspection the bridge was opened by the operator, who did not know that he was being timed. Beginning with the first movement to set the railroad signals—the signals were set at danger—the operator on the bridge received his signal to open, and the cold gasoline engine was started and operating speed was attained in 60 sec.; 20 sec. were required to lower the ends of the bridge; 5 sec. were used in throwing the clutches from the wedge-operating shafts to the bridge-turning shafts; and 85 sec. sufficed to open the bridge 90°; thus making the total time from the first motion of the signals to the fully open position of the bridge, 2 min. and 50 sec.

The speaker visited many draw bridges on the Pacific Coast, but did not see an operator's house, or a set of bridge mechanism, in such perfect condition as that on the Dumbarton Bridge. The bridge operator evidently took great pride in the maintenance of the structure. The bridge machinery, after practically two years' use, was as clean as one would expect to find well-maintained machines in a shop, and the operator's house, in all its appointments, was a model of neatness.

Lewis D. Rights, M. Am. Soc. C. E.—The author is to be congratulated on the concise and clear manner in which he has covered the engineering features connected with this bridge. The speaker is interested in the description of the erection of the steelwork, which seems to have proceeded in a very expeditious manner. Mr. Rights.

Mr. Schneider speaks of the novel construction of a derrick-car, which, according to the illustrations, consisted of a hinged **A**-frame placed on a standard flatcar. Such tools have become common in the East, and almost every bridge company owns one or more. Hinged **A**-frames of wood have been in use for some years, and, about ten years ago, S. P. Mitchell, M. Am. Soc. C. E., conceived the idea of building a special steel car with a hinged steel **A**-frame. A car of this kind was used successfully in connection with the erection of the Warehouse Point Bridge, where the New York, New Haven and Hartford Railroad crosses the Connecticut River, below Springfield, Mass. Mr. Mitchell then substituted heavy steel struts for back-stays.

Mr. Rights. patented the invention, and has built, or authorized the construction of, a number of cars. The **A**-frame is 23 ft. high, making the total height of the car when in use about 27 ft. Such height of mast is necessary for booms of 50 and 60 ft., and cars have been built recently with masts some 7 ft. higher. The standard overhead clearance for the Middle Western roads is 22 ft. above the rail, and as this is not sufficient to clear the top of the **A**-frame, Mr. Mitchell has made arrangements to lean the frame back and shorten the back-struts by a series of pin-holes in the latter. On some of the Eastern railroads, especially the New England roads, the overhead clearance is very much less than 22 ft.; in some cases it is only about 15 ft., with a minimum of 14 ft. 6 in. This is not much more than sufficient to pass a high furniture car, and it is not always practicable to lean the **A**-frame back far enough to be able to work under such clearances. In the last few years some of the Eastern concerns have attempted to overcome this difficulty by building a heavy steel frame, the top chords of which occupy about the same position as the eaves of a box car. One company has made the front posts of this frame hollow, so that an **A**-frame can telescope into them. An arrangement of pin-holes enables work to be done with an **A**-frame at a height very little above that of a box car, or to extend the frame so as to give a mast of about 18 ft. Several other companies have used this same type, but have hinged a short **A**-frame on the top of the steel truss, instead of at the car floor.

Another feature of interest in connection with the erection of the Dumbarton Bridge is the illustration of the double-headed traveler. It would seem that the single booms at each end of this traveler were designed with the idea of working alternately on the fixed spans, and that probably only one boom was worked to advantage at any one time. A single boom for the erection of a truss was not considered good practice several years ago, owing to the number of pieces which had to be held in place while a connection was being made, but the introduction of riveted joints has produced quite a change in methods. Recently, derrick-cars have been used very successfully in the erection of riveted trusses, although there are engineers and erectors who maintain that other tools are more efficient. In this matter, it is sometimes difficult to decide as to the most efficient method of erecting steelwork. Several years ago, the New York, New Haven and Hartford Railroad, in extending its six-track line into New York City, built a great number of overhead bridges for the separation of street and railroad grades. The bridges were designed for New York City paving standards and very heavy live loads, and consisted of three trusses with double roadways and sidewalks. The spans were not very long, 120 ft. probably being the average. It happened that during a period

of about 18 months, four different bridge companies secured contracts for four bridges, the details of which were very similar. They were all overhead highway bridges, with the erection conditions almost exactly the same, and the interesting feature was that each of the four companies used a different method of erection. Mr. Rights.

One company used a steel gallows, or gantry traveler, reaching above the trusses, and erected the steel from fixed hoists.

The second company erected two heavy steel derricks in the street, one at each abutment, with booms long enough to meet at the middle of the span.

The third company had two derrick cars, one of which was placed on the upper falsework and was used for erecting the trusses; the other was used down on the railroad grade to supply the upper one with material.

The fourth concern built a two-boom mule traveler, that is, a low-decked traveler with two masts and booms. The booms reached out over the falsework to get material from the cars below.

The speaker was interested in the erection of one lot of bridges, and watched carefully to see what the other companies were doing, in order to learn whether there was any marked difference in the methods. As far as he could see, each concern was guided in the choice of erection tools by what it had on hand, and there did not seem to be any very great advantage of one kind of tool over the other. The speaker is satisfied that the method in which he was interested was the best; but the representatives of the other concerns feel the same way about their methods, so that the question is still open.

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SHEARING STRENGTH OF CONSTRUCTION JOINTS IN STEMS OF REINFORCED CONCRETE T-BEAMS, AS SHOWN BY TESTS.

Discussion.*

By Messrs. J. P. Snow, D. Gutman, Elwyn E. Seelye, Alfred B. Heiser, Henry G. Raff, G. E. Doyen, and Thomas H. Wiggin.

J. P. Snow, M. Am. Soc. C. E.—It may be of interest, in this connection, to refer to the action of bolts in experimental timber joints, which are subjected to much the same shearing action as the stirrup rods in question. In the case of plain fished joints, without keys or notches in the timber, failure is always gradual, because the bolts crush into the wood, the bolts assuming a reverse curve and finally parting by tension when the slip becomes great enough to bring the reverse of the bolt at an angle of about 45 degrees. Mr. Snow.

The same action occurs in a wooden treenail or pin in plank lattice bridges. These pins are generally of oak, and the plank is spruce or pine. When slip occurs, the grain of the pin is somewhat crushed and an offset occurs which is somewhat like a reverse curve, but is never true shear.

The shearing strength and bearing value of concrete are so nearly equal that it is doubtful whether, in the authors' experiments, the stirrup rods added anything at all to the shearing strength of the joint between the stem and the slab, in view of the fact that no initial slip occurred.

Roughness of the joints is an undoubted benefit, because the contact area between old and new concrete is thereby greatly increased. The bonding material must possess as much shearing strength as the

* Continued from April, 1913, *Proceedings*.

Mr. Snow. mortar, or more, therefore steel is a good material for this purpose, but its great excess of strength is wasted as a help in increasing the shearing value of the joint.

Mr. Gutman. D. GUTMAN, M. AM. SOC. C. E.—The speaker would like to know whether it would have had any bearing on the test if the flanges had been made wider? In the average computation for floor-beams or girders, there is much more flange taken in by the contingent floor-slab than is shown. Of course, from abstract reasoning, that would not change the values for the shear; but those things act very queerly sometimes, and the speaker wonders whether the test might not have shown a great variation if there had been at least a foot on each side, because the building codes of various cities allow at least that much.

In practice, the floor-slab has a negative bending moment at the point of support, namely, the beam. That is to say, the flange of the T-beam would tend to bend downward if the test beam were actually loaded as it is in the building. This force would tend to lift the center portion of the flanges away from the stem.

Inasmuch as there is a greater number of shear bars present than the beam would contain in practice (which extra bars would take care of the effect of the negative bending moment of the slab), is it really fair to compare a separately poured flange and stem and a flange and stem poured in one operation?

Mr. Seelye. ELWYN E. SEELYE, ASSOC. M. AM. SOC. C. E.—The fact that the depth of the beams tested, in proportion to the span, is much greater than that which is ordinarily met in practice, and the fact that the reinforcing rods were either hooked or bent up at the ends, leads the speaker to suspect that the load was carried by arch action rather than by flexure, and, therefore, that the shear along the plane under discussion would be less than the authors estimate it to be. Also, as has been suggested, the presence of the stirrups hooked into the T-flange develops "punching" shear, and hence a higher value may be expected.

The speaker is constrained to take the position of a critic because he feels that it would be a serious matter if the idea got abroad among practical men that the beam and slab do not need to be poured in one operation. It is sufficiently difficult now for the engineer to have his construction joints placed where he wishes them.

Mr. Heiser. ALFRED B. HEISER, JUN. AM. SOC. C. E.—The authors claim to have made a comparative test between smooth and corrugated joints in beams having the flange poured some days later than the web. However, such a comparison is not made, for in none of the specimens tested did the joint fail. All that is proved is that when sufficient stirrups are placed across the joint it will not rupture under the breaking load of the beam.

When beams of this character are used in construction work, there are a number of conditions which do not exist in laboratory practice. In hoisting the beams into position they are jarred and pretty well shaken, thus tending to break the bond between steel and concrete. After the beam is in place and the slab is poured, forms are dropped on it, vibrations of the building shake and jar it, and temperature stresses warp it, all of which tend to destroy the bond between the web and the flange. One year after placement, a beam is likely to have a very imperfect bond between the web and the flange. Any decrease in the grip of the stirrups on the concrete will decrease the frictional resistance along this plane. Mr. Heiser.

In answer to the three objects of the tests, as stated in the paper, it may be said:

1.—That this type of construction is safe for buildings only when sufficient stirrups are placed across the joint.

2.—The tests do not warrant any omission of corrugations, except when using the same proportion of stirrups as in the test. About three times the quantity of stirrups recommended by the Joint Committee were used in these tests.

3.—The authors have not discovered how high a shearing stress the smooth joint will resist, for the joint did not fail.

Beam No. 28 has seven $\frac{5}{16}$-in. round stirrups and two $\frac{3}{4}$-in. square bars crossing the joint between the load and the support. The seven stirrups have an area of 1.0738 sq. in. This, resolved through an angle of 45°, in order to resist diagonal tension, is 0.75 sq. in. Adding 1.62 sq. in. (area of diagonal bars) to this gives 2.37 sq. in. of steel resisting the tension imposed by the main steel. This gives a unit stress of $\frac{91\,044}{2.37} = 38\,400$ lb. per sq. in.

The total tension in the beam is derived by multiplying the area of the tension steel, 1.62 sq. in., by the unit stress in Table 2, 56 200, which gives 91 044 lb. This does not exceed the elastic limit, and certainly shows that the concrete is not stressed.

The authors would do better if they tested a beam with stirrups in the web (sufficient to resist diagonal tension) and with only two or three stirrups across the joint. The beam would then probably fail along the construction joint, thus giving a means of comparison between the two styles of joint, and also values for these joints.

The authors state in the introduction that they are endeavoring to find an economical construction. Stirrups cost money, and if some can be omitted there would be a saving. These tests do not give any means whereby the stress in the stirrups can be measured; a test worth while ought to give the strength of the joint, so that it would be possible to ascertain the number of stirrups necessary to reinforce it.

Mr. Heiser. The conclusions drawn by the authors are misleading, and might cause disaster if used by an incompetent designer.

On first reading the paper, one would think that, with the ordinary quantity of stirrups, as recommended by the Joint Committee, a construction joint is permissible in a beam, for the authors do not give their method of calculating these stirrups. As the majority of the members have only time for a first reading, it is thought that this paper might cause laxity in pouring methods.

Mr. Raff. HENRY G. RAFF, M. AM. SOC. C. E.—The speaker has read this paper with interest, and feels that the authors are entitled to many thanks for publishing the description and results of their experiments.

The question of construction joints in concrete and reinforced concrete construction has long been, is, and will continue to be, a bone of contention between the contractor and the engineer. All efforts to solve this problem in a practical way should, and undoubtedly will, receive hearty endorsement by the members of this Society.

In describing the various types of beams, the paper states that the Type *A* beams were similar to those going into the actual construction. The speaker assumes that these test beams were similar to, but not identical with, those comprising the floor system of the buildings.

The paper also states that the sections of these test beams, and the reinforcement therein, were designed with the idea of developing high shearing stress in the stems, and, in order to obtain this condition, the various sections and the reinforcement were of more than ordinary size and quantities.

The question that naturally presents itself is, to what extent should actual construction work be governed by the results of these tests? The favorable results shown are very encouraging; however, the speaker would advise caution in the matter, and allow the present method of monolithic construction to prevail until such time as tests on actual construction members prove the advisability of permitting these construction joints in actual practice.

The test beams, *A* and *C*, having the same cross-section and span length (though the quantity of stirrups in *A* is greater than in *B*), permit of direct comparison, and lead to the conclusion that the stirrups assist the construction joint in taking shear. The test beams, *A* and *B*, or *C* and *B*, being of unequal spans, do not permit of this direct comparison, but, eliminating the consideration of the different quantity of stirrups therein, an interesting comparison may be made with reference to span length; likewise, eliminating the consideration of the unequal length of spans, a comparison may be made with respect to the quantity of stirrups contained in them.

Table 3 has been derived by averaging the various groups of "results of tests" given in Table 2, and may prove to be of interest.

TABLE 3.

Mr. Raff.

No.	Type.	Joint.	Total load.	Stress on concrete, in pounds per square inch.	Total shear.	Shear area at construction joint, in square inches.	Shear per square inch.	Total stirrup area at joint, in square inches.	Percentage of stirrup area, in terms of shear area.	Span of beams, in inches.
1...	*A*	Smooth............	50 700	2 885	230 000	400	575	2.76	0.69	100
2...	*A*	Corrugated	47 500	2 733	217 200	400	543	2.76	0.69	100
3...	*A*	Monolithic.	49 800	2 815	225 200	400	563	2.76	0.69	100
4...	*B*	Smooth............	51 800	2 573	214 928	304	707	5.06	1.66	76
5...	*B*	Corrugated	60 600	2 980	250 192	304	823	5.06	1.66	76
6...	*B*	Monolithic.	55 550	2 695	227 392	304	748	5.06	1.66	76
7...	*C*	Smooth............	43 100	2 665	201 600	400	504	0.99	0.25	100
8...	*C*	Monolithic........	46 350	2 720	210 8 0	400	527	0.99	0.25	100

Assuming the stirrups to be capable of taking horizontal shear to the amount of the product of their normal projection on the plane of the construction joint by the ultimate (unit) crushing strength of the concrete (as determined by the average of the stresses given in Table 3), we have a value in horizontal shear for one $\frac{3}{16}$-in. stirrup of $(2\,741 \times 0.1875) = 514$ lb.; a value in horizontal shear for one $\frac{5}{16}$-in. stirrup of $(2\,741 \times 0.3125) = 857$ lb.; and for one $\frac{3}{8}$-in. stirrup a value of $(2\,741 \times 0.375) = 1\,028$ lb. There were 36 stirrups in each beam, hence the total value in horizontal shear of the $\frac{3}{16}$-in. stirrups per beam is 18 504 lb., of the $\frac{5}{16}$-in. stirrups per beam the value is 30 852 lb., and of the $\frac{3}{8}$-in. stirrups per beam the value is 37 008 lb.

Table 4 gives the results obtained by deducting these assumed values of the stirrups in horizontal shear from the total shear on the construction joints of the various beams, subtracting from the gross area of these joints the area of their respective stirrups, and dividing the net shear in concrete by the net concrete area of the construction joints.

TABLE 4.

No.	Type.	Joint.	Total shear at construction joint.	Total shear in stirrups.	Total net shear in concrete.	Net concrete area, in square inches.	Total stirrup area, in square inches.	Shear in concrete per square inch.	Span of beams, in inches.
I	*A*	Smooth..................	230 000	30 852	199 148	397.24	2.76	501	100
II	*A*	Corrugated	217 200	30 852	186 348	397.24	2.76	469	100
III	*A*	Monolithic	225 200	30 852	194 348	397.24	2.76	490	100
IV	*B*	Smooth..................	214 928	37 008	177 920	298.96	5.06	595	76
V	*B*	Corrugated	250 192	37 008	213 184	298.96	5.06	713	76
VI	*B*	Monolithic	227 392	37 008	190 384	298.96	5.06	636	76
VII	*C*	Smooth..................	201 600	18 504	183 096	399.01	0.99	459	100
VIII	*C*	Monolithic	210 800	18 504	192 296	399.01	0.99	483	100

Mr. Raff. Table 5 will undoubtedly prove interesting because of the extraordinary results shown in the column headed "Percentage of low shear in terms of high shear." The speaker feels that, irrespective of the various causes contributing to these erratic results, they should receive profound study by the engineer who contemplates the use of construction joints in T-beams similar to those under discussion.

TABLE 5.

Comparison of beams by numbers.	Unit shear from Table 3.	Unit shear from Table 3.	Unit shear from Table 4.	Unit shear from Table 4.	Percentage of low shear in terms of high shear.
1 and 7	1 at 575 lb.	7 at 504 lb.	....	....	88
1 and VII	....	....	I at 501 lb.	VII at 459 lb.	92
3 and 8	3 at 563 lb.	8 at 527 lb.	....	....	93
III and VIII	....	....	III at 490 lb.	VIII at 483 lb.	100
4 and 1	4 at 707 lb.	1 at 575 lb.	....	....	81
IV and I	....	....	IV at 595 lb.	I at 501 lb.	84
4 and 7	4 at 707 lb.	7 at 504 lb.	....	....	71
IV and VII	....	....	IV at 595 lb.	VII at 459 lb.	77
5 and 2	5 at 823 lb.	2 at 543 lb.	....	....	66
V and II.	....	....	V at 713 lb.	II at 469 lb.	66
6 and 3	6 at 748 lb.	3 at 563 lb.	....	....	75
VI and III	....	....	VI at 636 lb.	III at 490 lb.	77
6 and 8	6 at 748 lb.	8 at 527 lb.	....	....	70
VI and VIII	....	....	VI at 636 lb.	VIII at 483 lb.	76

Mr. Doyen. G. E. Doyen, Esq.—According to the usual method of calculating stirrups, there seem to be too many in these beams, particularly in those of Type *B*. The usual method of calculating assumes 120 lb. per sq. in., or, at most, 150 lb. per sq. in., on the net section as the allowable shear, and that one-third of this is carried by the concrete and the remainder by the stirrups and bent-up bars. Where there are no bent-up bars, as in this case, the speaker would calculate the stirrups as follows: Width of beam multiplied by unit shear carried by stirrups = 4 in. $\times$ 100 lb. = 400 lb.; value of two $\frac{3}{8}$-in. square bars at 16 000 lb. per sq. in. = 4 500 lb.; the stirrup spacing would then be $\frac{4\ 500}{400}$ = $11\frac{1}{4}$ in., or practically three times that actually used. This spacing is too wide for the beam in question, and smaller steel should be used.

The result of using so much stirrup steel is that the web and flange of the beam are so thoroughly tied together that there is no chance for a shear crack to form between them. If the stirrups act in tension, as assumed, and as they undoubtedly do after the web of the beam has begun to crack, there is a direct pull by each stirrup on the flange of the beam, which amounts to quite a considerable force. This pull brings into play a frictional resistance between the two parts of the beam, which acts in addition to any adhesion of the concrete surfaces.

Aside from this factor, there can be no doubt that the stirrups prevent any such lifting up of the flange as would be necessary in order that it might slip over the rough surface of the top of the web. Mr. Doyen.

In short, the authors have attempted to find how high a shearing stress a smooth joint between the web and flange of a concrete beam would carry, but have only discovered that, by using a quantity of stirrup steel greatly in excess of what would be used in practical design, it is possible to tie the two parts of the beam together so thoroughly that they are able to obtain a very high unit shear. The tests do not show how high a shear such a joint would stand in a beam designed to meet practical conditions.

THOMAS H. WIGGIN, M. AM. SOC. C. E.—The speaker is not in accord with those who have suggested the absence of shear on the joints tested; he believes it must be conceded that there is shear on these joints, and that the vertical shear rods in themselves cannot take it. The rods are not placed in the right position to take the horizontal shear, being at right angles to that stress; and the bearing area which they have on the concrete above and below would be inconsiderable compared with the shear to be resisted. The shear must be carried by the strength which has been developed in the construction joint, explained by excellent adhesion or by some other phenomena, which the discussions thus far have not disclosed. Mr. Wiggin.

With respect to the adhesion as bearing on the integrity of the concrete across the joints, that, of course, is a question of methods of construction. Strong adhesion can easily be obtained in an experimental way, which might not be carried on with such uniform success on a larger scale; for example, the dirt on the surface can all be removed, and with certainty, though it is understood that it was not done in this case. Dirt can be prevented from getting on the concrete and a higher degree of workmanship can be secured than would be generally possible on a large scale.

It has often been shown in experiments that beams of plain concrete can be made in two operations, using rich mortar at the joint, and that these will break elsewhere than at the joint; yet, in construction, if any cracking occurs in concrete, it is usually at the joints and not elsewhere. The speaker has noticed this repeatedly in various shrinkage phenomena, and in testing concrete pipes by water pressure.

One may concede that the methods used were fairly representative of commercial work, and still find an explanation for the strength developed. In tests of what is sometimes called "true" shear, it is very seldom that the breaking stress is less than 700 or 800 lb. It frequently runs up to 1 000 or 1 100 lb., and results greater than 2 000 lb. have been obtained in punching shear on plates with edges

Mr. Wiggin. bound by reinforcement.* Now, what is there that distinguishes punching shear from ordinary shear developed in beams resting on supports? The nearness of the load to the point of support and the binding force supplied by the grips—and particularly by the steel in the tests, above mentioned, of punching shear on concrete plates with edges reinforced—probably both contribute to the high results; and it is not difficult to conceive that the stirrup steel produced a similar effect in the tests under discussion. The action conceived of is not that suggested by one speaker—that the tension in the stirrup steel causes a friction between the two concrete surfaces assumed to be plane—for tension would cause the stirrups to stretch slightly, thus taking the concrete out of bearing, and precluding friction of the ordinary kind, such as would exist between plane surfaces held together. As no surface under the microscope is smooth (and particularly a concrete surface), it is entirely conceivable that, although the stirrup rods may stretch to a slight extent, they would still hold the teeth of the surfaces, so to speak, in mesh, and thus cause an action similar to punching shear, though not as effective on account of the general absence of pieces of the coarse aggregate across the plane of shear. A minute distortion would have to take place before such action could occur, but it would be very minute with the quantity of stirrup steel used in the beams under discussion.

The speaker offers this as a purely off-hand and unstudied speculation, although it is perfectly certain that, with good workmanship, a joint would frequently be made that would be just as strong as the original concrete. If the explanation suggested has any weight, it is true, of course, that a large number of stirrups would be more effective than a small number, so that there may be something in the criticism in the discussion that the relatively large quantity of stirrup steel does have an effect on the results. The speaker thinks more investigation would be wise before applying the method described by the authors to ordinary designs of reinforced concrete over large floor areas.

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* *Bulletin No. 8*, University of Illinois Engineering Experiment Station.

AMERICAN SOCIETY OF CIVIL ENGINEERS

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PAPERS AND DISCUSSIONS

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KINETIC EFFECTS OF CROWDS.

Discussion.*

By Messrs. Frazer C. Hilder, Henry H. Quimby, R. D. Coombs, and J. B. French.

Frazer C. Hilder, Assoc. M. Am. Soc. C. E. (by letter).—This paper is a valuable addition to the scanty data on the loads to be expected on a structure crowded with moving people. It would seem to the writer that more extended experiments along these lines might well be undertaken to determine the horizontal component of the kinetic effect produced by a crowd moving in unison on a grand stand or similar structure. A considerable horizontal force is evidently exerted by a crowd of "rooters," not only by springing to their feet at the crucial moment of an exciting game, as considered by Mr. Tilden, but by moving rhythmically thereafter so as to produce and continually accentuate a rocking motion in the structure. The writer has in mind an instance coming under his observation where a wooden stand was dangerously racked by a crowd of excited students swaying in unison, from one leg to the other, as they sang. While such ebullitions might well be suppressed in the interests of safety, it is evident that in spite of precautions such movement may occur, and that the possibility should be considered in the design of a grand stand, particularly for a college. Mr. Hilder.

While such an investigation would indicate the need of excessively heavy bracing, if an ordinary factor of safety were used, it would seem that a structure of the class indicated might well be designed to resist the possible rocking or marching of a crowd, with a small factor of safety, as compared with that calculated for static loads.

* This discussion (of the paper by C. J. Tilden, Assoc. M. Am. Soc. C. E., published in March, 1913, *Proceedings*, and presented at the meeting of April 16th, 1913), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

Mr. Quimby.

HENRY H. QUIMBY, M. AM. SOC. C. E. (by letter).—Any suggestion of new forces to be provided for in the design of structures will awaken the interest of a structural engineer, and, therefore, the experiments described in this paper command attention. The statement that a man in rising suddenly from a seat may exert a horizontal effect or force equal to one-half his weight, is somewhat startling; and that a grand stand should be figured for a horizontal force equal to one-half of all its vertical live load is a new proposition, which, if true, is important.

In order to test the proposition, the writer rigged up a means of measuring horizontal impulses by attaching adjustably loaded brackets to a light swinging platform; he also experimented with the swing disconnected from the loads, in order to observe the amount of the induced lateral movement.

The greatest backward horizontal force produced by a sudden rising from the seat with the consequent shifting forward of the center of gravity of the body, appeared to be 7% of the body weight, and the backward swing of the unrestrained platform indicated only 5% when the weight was multiplied by the tangent of the angle of inclination of the suspenders. The latter is probably not at all reliable, because the amount of the lateral swing is not likely to be in direct proportion to the length of the suspenders, and, without doubt, the backward swing was always interrupted by the forward impulse.

It was immediately observed that the re-acting forward force was much greater than the rearward force. The unrestrained platform—disconnected from the apparatus and free to swing—would first swing backward about 4 in., and then about 8 in. forward of the neutral point. When it was restrained, the weight lifted by the second or return impulse was about twice as great as that lifted by the first or backward impulse, that is, about 14% of the vertical load.

These measurements seem to indicate that there is something wrong with the author's method of computing the horizontal effect. The error is probably in the assumption that the horizontal movement is as rapid as the vertical one. A study of the movement shows that either the center of gravity is thrown forward before rising, or the feet are drawn under the body and, after rising, the body steps forward, for the rise could not be made in the inclined direction without a "purchase" to the rear to push against. Speed of movement is essential to the development of kinetic energy.

The rearward impulse is succeeded so quickly by the forward one that the bracing of the structure has hardly time to feel it, and its energy must be largely absorbed by the inertia of the structure if the dead weight is at all considerable, and this is likely to be the case always. The platform used in the experiment described was very

light—perhaps one-fifth of the live load—as probably was that of the scale used by the author in his work. Absorption of energy of a transitory force reduces the effect and the attending stress, as illustrated by the old magic of enduring a sledge-hammer blow on one's chest by interposing an anvil. It is suggested that the author repeat his rising experiment on the scale with its platform loaded with a dead weight equal to the live load, and report the result. Mr. Quimby.

The fact that the second or forward impulse is greater than the rearward one, is probably due to the arrest of the movement being more sudden than its start. The energy expended in the movement must be divided between accelerating it and retarding it, but the kinetic effect will be proportioned to the quickness of each stage.

The stress, or the effect of stress, in a structure is not directly proportional to the speed of application of loads—it is not necessarily increased by so-called impact. Within limits, the rapid application of a load to almost any material will find a higher resistance than a slow application, and if the dead weight be equal to, say, the live load, much of any kinetic effect of sudden loading will be lost in the mass before reaching the bracing.

The effect of a crowd running across a bridge and against the railing is a more menacing force, and at least one case is recalled where a footbridge over a stream collapsed under a shifting crowd of spectators at a boat race. A well-designed bridge railing, however, will be competent to resist the pressure of a crowd, for if the strength of the rail and the posts be computed for 50 lb. per lin. ft. applied at the rail, the usual allowed unit stress will provide ample margin for a push against it. The kinetic effect of a crowd hurrying across the bridge would be spent in the floor and not on the railing, for only one rank of the runners could fetch up against the rail—at least, at one moment—and a bridge wide enough to permit a shifting crowd to get up any speed must have considerable mass or inertia, and is likely also to be stiff as a horizontal beam.

It would seem, therefore, that we hardly need to revise our practice in the design of structures to care for a new kind of impact. The suggestions in the paper, however, should be useful in directing attention to the necessity for intelligent design in the construction of all parapet railings, but the most formidable impact that railings are subject to nowadays seems to be that of straying trolley cars and automobiles, one of the former and half a dozen of the latter having come under the writer's notice recently, and engineers cannot well be expected to design for such contingencies.

R. D. Coombs, M. Am. Soc. C. E.—It seems to the speaker that the general application of the results of the experiments to specifications, by the addition of loading requirements, would be an unneces- Mr. Coombs.

Mr. Coombs. sary burden to structures which are calculated for wind load. Such structures, particularly if designed for the venerable loading of 30 lb. per sq. ft., would have a strength more than sufficient to care for the lateral stresses due to the movement of the live load. In fact, the calculated wind load would not occur while the structure was occupied, as the load presupposes a very violent wind velocity. Further, the usual so-called "wind loads" really include a vibration, or lateral impact loading.

Though some special provision for lateral and vertical impact forces may be proper for light temporary grand stands, etc., which may not be designed for the usual wind loads, the speaker believes any such addition entirely unnecessary for first-class permanent work.

Mr. French. J. B. French, M. Am. Soc. C. E.—The author's experiments are of interest and merit discussion, but, as pointed out by Mr. Prichard, the effect of these forces on structures is very largely dependent on the general character and dimensions of the structure, independent of its strength. If the intervals of time between the successive applications of even a very small force correspond to the rate of vibration of the structure or structural member, the effect will be cumulative and may assume serious proportions.

The most extensive experiments on structures to determine the kinetic effect, as distinguished from the static effect, of moving loads, are undoubtedly those made by the American Railway Engineering Association by running trains across bridges, the length, weight, and speed of the trains, and the length of the bridges all being varied within considerable limits; and, in these experiments, it appeared to be demonstrated that the kinetic effect, or impact produced, depended largely on the relation of the span length to the speed and length of the train, and that the running of trains over bridges at a speed of less than 10 miles per hour produces no appreciable effect beyond that which would be produced by the train standing still.

The effect of the movement of crowds over bridges would certainly be dependent on similar laws, and it does not seem possible that a bridge designed to carry the automobile and heavy trucking traffic of to-day, and constructed with the solid floors which are now so common, could be appreciably affected by the dynamic effect of crowds of people.

In the case, however, of grand stands filled with spectators of a football or similar game appealing to their enthusiasm, all might arise at one time and engage in regularly timed cheering or stamping, thereby, undoubtedly, producing a considerable effect, and this should be taken into account in the design of such structures. Even in this case, however, it is evident that the effect would be more dependent on the rigidity of the structure, or what might possibly be called its "vibratory pitch," than on its strength under static loads, or the weight of the spectators.

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SOME EXPERIMENTS WITH MORTARS AND CONCRETES MIXED WITH ASPHALTIC OILS.

Discussion.*

By Messrs. Logan Waller Page, William J. Boucher, and A. T. Goldbeck.

Logan Waller Page, M. Am. Soc. C. E. (by letter).—Since reporting the results of his oil-concrete investigations† in September, 1911, additional data have been obtained by the writer which will be of interest at the present time in showing the effect of different types of oils on the strength of oil-mixed concrete and mortar at the age of 2 years. These results, some of which have already been reported at an early age, are given in Tables 10, 11, and 12. Mr. Page.

Referring first to Table 10, Tensile Strengths, it will be noted that Oils Nos. 4923, 4981, and 5053 have no deteriorating effect on the tensile strength, at the end of 1 year in the case of No. 5053, or at the end of 2 years in the cases of Nos. 4923 and 4981. Oil No. 5856 more nearly resembles those used by Messrs. Taylor and Sanborn than any of the others, and the effect on the strength is not greatly different from that reported by them. The few tests made with Oil No. 6536, at the end of 28 days, show an increase in the tensile strength with the addition of this oil. It would seem from these results, combined with those of Messrs. Taylor and Sanborn, that some types of oils might be seriously detrimental to the strength of mortars, and, therefore, that their selection should be made from the results of tests of mortar mixed with the oil under consideration.

* This discussion (of the paper by Messrs. Arthur Taylor and Thomas Sanborn, published in the March, 1913, *Proceedings*, and presented at the meeting of April 16th, 1913), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† *Transactions*, Am. Soc. C. E., Vol. LXXIV, p. 255.

Mr. Page.

TABLE 10.—TENSILE STRENGTH OF OIL-MIXED BRIQUETTES STORED IN WATER.

1 : 3 Ottawa Sand.

Mark.	Percentage of oil.	Character of oil.	7 days.	28 days.	6 months.	1 year.	2 years.
16	0	Fluid residual oil No. 4 923	256	296	326	326	293
17	2½	"	299	400	449	320	257
18	5	"	287	316	372	353	...
19	10	"	252	331	360	343	315
20	15	"	268	356	308	327	320
21	20	"	250	335	320	340	333
152	0	Fluid residual oil No. 4 981	283	367	312	...	250
158	2½	"	259	327	323	...	296
163	5	"	268	341	321	...	328
160	10	"	264	329	319	...	265
213	0	Fluid residual oil No. 5 053	244	331	302	288	...
216	2½	"	297	353	298	286	...
217	5	"	313	334	325	309	...
222	10	"	304	371	330	320	...
579	0	Asphaltic petroleum No. 5 856	226	343	348	340	...
580	2½	"	238	297	278	333	...
581	5	"	204	295	323	295	...
582	10	"	161	225	276	285	...
733	0	Asphaltic petroleum No. 6 536	...	347	...	...	...
734	5	"	...	385	...	...	...
735	10	"	...	370	...	...	...

The results on crushing strength given in Table 11, and extending up to a period of 2 years, show, in general, that oil-mixed concrete gains strength with age, a pretty strong indication that, with the small quantity of oil incorporated, the concrete is not likely to suffer future deterioration. The ratio of the strengths, however, is not the same with different kinds of oils. When 10% of Oil No. 4981 is mixed with concrete, the strength is cut down to about one-half of that of the plain mixture at all periods up to 2 years. Oil No. 4923, however, does not have this severe effect in decreasing the strength; and, in general, with a very dusty crushed gneiss aggregate, the crushing strength with 10% of oil is about 75% of that of the plain concrete, and with 5% of oil is about 85% of the plain concrete strength. With a well-graded, clean, gravel aggregate, excellent results were obtained with 2½, 5, and 10% of Oil No. 4923, the 5% mixture having 93% and the 10% mixture 90% of the strength of plain concrete. The results obtained at the end of 1 year, on the compressive strength of mortar mixed with five different kinds of oils, and reported in 1911, do not show the serious decrease in strength obtained by Messrs. Taylor and Sanborn with the California asphaltic oils.

Regarding the question of absorption, it is to be regretted that the authors have not explained thoroughly their absorption tests, particularly with regard to the preliminary treatment of their specimens in securing complete dryness. It has been the writer's experience,

Mr. Page.

TABLE 11.—CRUSHING STRENGTH OF OIL-MIXED CONCRETE.

Specimens 6 *c* to 12 *c* are of 1:3:6 concrete.— Crushed gneiss aggregate.
" 13 *c* " 18 *c* " " 1:3:5 " — " " "
" 164 " 224 " " 1:1.5:4.5 " — " " "
" 479 " 482 " " 1:2:4 " — Gravel aggregate.

Mark.	Percentage of oil.	Character of oil.	Stored in Air.				Stored in Water.			
			28 days.	6 months.	1 year.	2 years.	28 days.	6 months.	1 year.	2 years.
6 *c*	0	....	1 020 (3)	980 (2)	1 090 (3)	1 225 (2)	1 370 (2)	1 955 (2)	2 170 (3)	2 205 (2)
7 *c*	2½	Fluid residual oil No. 4 923	750 (2)	915 (2)	1 165 (2)	....	1 253 (3)	1 715 (2)	1 580 (3)	1 900 (2)
8 *c*	5	"	711 (2)	975 (2)	1 015 (2)	1 560 (2)	1 142 (2)	1 690 (2)	1 835 (2)	1 865 (2)
9 *c*	10	"	656 (2)	755 (2)	850 (1)	1 230 (1)	961 (3)	1 400 (2)	1 140 (3)	1 585 (2)
10 *c*	15	"	542 (2)	670 (2)	675 (2)	....	750 (2)	995 (2)	1 145 (3)	....
12 *c*	25	"	605 (3)	678 (2)	....	1 005 (2)	620 (3)	1 030 (2)	1 120 (2)	....
13 *c*	0	....	920 (2)	998 (3)	1 010 (1)	1 100 (2)	1 342 (3)	1 705 (3)	1 890 (3)	2 300 (2)
14 *c*	2½	Fluid residual oil No. 4 923	787 (2)	945 (2)	995 (3)	1 010 (2)	1 250 (2)	1 830 (3)	2 410 (3)	2 250 (2)
15 *c*	5	"	720 (2)	822 (2)	912 (3)	940 (2)	1 082 (2)	1 626 (2)	1 715 (3)	1 805 (2)
16 *c*	10	"	698 (2)	965 (2)	975 (2)	1 010 (3)	1 040 (2)	1 406 (2)	1 490 (3)	1 480 (3)
17 *c*	15	"	693 (2)	828 (2)	888 (3)	888 (2)	1 040 (2)	1 380 (2)	1 382 (3)	1 680 (3)
18 *c*	20	"	572 (2)	639 (2)	772 (2)	672 (2)	904 (2)	1 116 (3)	1 230 (3)	1 130 (2)
164	0	....	1 880 (2)	2 050 (2)	2 365 (2)	....	2 185 (2)	2 670 (2)	2 950 (2)	2 870 (2)
168	2½	Fluid residual oil No. 4 981	1 345 (2)	1 490 (2)	1 560 (1)	1 855 (2)	1 795 (2)	2 33 (2)	2 250 (2)	2 700 (2)
169	5	"	1 250 (2)	1 145 (2)	1 768 (2)	1 585 (2)	1 925 (2)	2 355 (2)	2 750 (2)	2 800 (2)
177	10	"	980 (2)	845 (2)	1 170 (2)	....	1 065 (2)	1 485 (2)	1 625 (3)	1 568 (3)
215	5	Fluid residual oil No. 5 053	622 (2)	846 (2)	830 (3)	847 (2)	1 250 (2)	1 570 (2)	1 627 (3)	1 829 (3)
221	10	"	841 (2)	798 (2)	1 015 (2)	....	1 164 (2)	1 590 (2)	1 768 (2)	1 710 (2)
224	15	"	643 (2)	752 (2)	800 (2)	....	1 320 (2)	1 710 (2)	1 730 (2)	1 535 (2)
Gravel 479	0	....	....	....	....	....	1 920 (3)	3 280 (3)	3 350 (3)	....
480	2½	Fluid residual oil No. 4 923	....	....	....	....	2 420 (2)	3 430 (2)	3 390 (2)	....
481	5	"	....	....	....	....	2 750 (3)	3 270 (3)	3 110 (2)	....
482	10	"	....	....	....	....	2 160 (3)	2 820 (2)	3 020 (3)	....

Mr. Page. and likewise that of other investigators, that a 1:3 mortar which will absorb only $2\frac{1}{2}\%$ of its weight during an immersion of 24 hours, is a rare curiosity. With all the oils that the writer has tried for absorption, he has obtained results the opposite of those reported by Messrs. Taylor and Sanborn. It has been his experience that the heavy oils are more effective as damp-proofers than the lighter oils, when properly mixed. The difficulty of mixing an oil with concrete increases with its specific viscosity, and it is unwise to use an oil with a higher specific viscosity than 45.

TABLE 12.—Analysis of Oils.

Sample number	5 856	6 536
Type	Asphaltic petroleum	Asphaltic petroleum.
Character	Sticky, viscous fluid, with gasoline odor.	Slightly sticky fluid, with naphtha odor.
Specific gravity at 25°/25° cent.	0.945	0.945
Loss at 163° cent., 5 hours, 20 grammes.	30.84	21.76
Character of residue	Soft, sticky, ductile, with slight flow	Soft, sticky, semi-solid, crystalline appearance on surface.
Soluble in CS_2, air temperature	99.93	99.97
Organic matter insoluble	0.07	0.03
Percentage of total bitumen insoluble in 86° paraffin naphtha	7.71	14.42
Fixed carbon	4.22	7.57
Specific viscosity, Engler at 25° cent.	50.0	15.0

The authors' permeability results are not a surprise to the writer, considering the early age at which the tests were made. As time goes on, the oil-mixed specimens, under high pressures, as well as the plain specimens, become impermeable, but, at early periods, oil-mixed concrete, under high pressure, is no more impermeable than plain concrete, although the writer has succeeded, even at early periods, in making the oil mixture of concrete more impermeable than the plain mixture, by using a very carefully graded gravel aggregate. Oil-mixed mortars seem to be, in general, impermeable. The writer would like to make it clear that he considers the addition of oil to the concrete mixture of benefit as a damp-proofer rather than as a means for preventing the percolation of water under great pressure; and not only his laboratory tests, but the results from numerous constructions, point to the efficiency of the oil as a damp-proofing agency. Oil-mixed mortar, however, might be used with benefit to prevent the percolation of water under pressure, as well as to damp-proof.

The writer has had very successful results with oil-mortar parging applied to the exterior, and in some cases to the interior, of basement walls, with oil-concrete roofs and walls, in the United States Treasury vaults, and in basement floors. He has also had reports regarding oil-mixed concrete structures that were perfectly waterproofed when subjected to heads of 10 ft. Oil-mixed concrete has likewise been used for the construction of pumping pits in very wet

soil. Similar constructions of plain concrete in the vicinity were always wet, whereas the oil-concrete constructions remained perfectly dry. The ease with which the oil can be incorporated with the concrete, and the comparative cheapness of the process, make it a desirable one for use in structures subjected to low heads. The following specification for oil is given as one which, it is believed, will give effective results as a damp-proofing agent when used in a concrete or mortar mixture: Mr. Page.

SPECIFICATION FOR OIL TO BE USED IN OIL-CEMENT CONCRETE.

(1) The oil shall be a fluid residual from the distillation of petroleum, and shall contain no admixture of fatty or vegetable oils.

(2) It shall have a specific gravity of not less than 0.920 at a temperature of 25° cent.

(3) It shall show a flash point of not less than 150° cent. by the closed-cup method.

(4) When 240 cc. of the oil is heated in an Engler viscosimeter to 50° cent., and maintained at that temperature for at least 3 min., the first 100 cc. which flows out shall show a specific viscosity of not less than 15 nor more than 30.

In conclusion, it would seem to the writer that, should a duplication of the tests by Messrs. Taylor and Sanborn give the same results with the California oils as those already obtained, they would be dangerous and valueless oils to use. The writer cannot help being a little doubtful of the reported absorption tests, as they are at variance with those of a number of investigators. He regrets that his own experiments have not included the California oils, but rather the semi-asphaltic product. He hopes, however, to be able to duplicate the authors' tests with the asphaltic oils, in order to throw additional light on their application to oil-concrete mixtures.

Regarding the effect of drippings of oil on concrete, it must be acknowledged that in a great many instances the concrete mixtures have suffered great deterioration. This, however, is an entirely different proposition from that of mixing oil in very small percentages with wet concrete. A great many lubricating oils have vegetable and animal oil admixtures, and such oils, it is known, cause the destruction of concrete, the lime in the cement causing a saponification of the oil. Moreover, in such cases, as the oil is concentrated on a small surface of concrete, its effect is very serious. In the case of the oil admixture, only a very small percentage of oil is used, and this is distributed throughout the mass.

WILLIAM J. BOUCHER, ASSOC. M. AM. SOC. C. E.—The following brief remarks do not relate to the asphaltic or other heavy oils, but to the lighter varieties, such as kerosene. Mr. Boucher.

Mr. Boucher.

In the period just preceding the opening of the present Rapid Transit Railroad, in New York City, barrels of kerosene were kept at convenient locations, from which the lanterns of the watchmen were filled. One night a barrel leaked, and in the morning an oily spot on the concrete roadbed showed where the kerosene had disappeared. Considerable discussion followed as to whether damage would result, and on account of the layers of asphalt and felt water-proofing about 10 in. below the surface of the concrete, which it was believed would surely be damaged by the kerosene, the concrete was dug up, the water-proofing relaid, and new concrete placed. It has always been a matter of interest to the speaker as to what would have happened to the kerosene-soaked concrete if it had been left in place. Probably on a smooth troweled surface, such as a sidewalk or station platform, it would run off and evaporate, but would it cause deterioration if allowed to remain in ordinary concrete?

On looking up some references on oil mixed with concrete, the speaker found a very interesting article,* giving the experiments and part of the conclusions of James C. Hain, Assoc. M. Am. Soc. C. E., who conducted quite an elaborate series of tests on cement briquettes, treated with or immersed in lard oil, whale oil, castor oil, boiled linseed oil, crude petroleum, and signal oil (the latter a mixture of animal fat and mineral oil). Mr. Hain's account of the tests covers more than three pages, and he summarizes as follows:

"At the outset we failed to find [in railroad or industrial works] a specimen of concrete that we felt was positively disintegrated by oil, though we not infrequently heard of it. * * * On the other hand, plenty of concrete was found that oil had penetrated but not disintegrated. Further, our tests on comparatively new briquettes, which were weakened by exposure to air, showed that, with one exception, they were disintegrated by all classes of oils and fats. These oils and fats when arranged according to their effect (as far as our experiments indicate), are as follows: 1, animal fat; 2, animal oil; 3, vegetable oil; and 4, mineral oil. * * * On the following points we are reasonably certain: (1) Most oils penetrate concrete mortar, which makes them dangerous. (2) Concrete is more liable to be disintegrated when saturated with oils and fats if not thoroughly set. (3) A good quality of concrete is less susceptible to the effect of oil than a poor quality, such as a porous, frosted, lean, poorly mixed, or improperly seasoned concrete."

In the issue of April 20th, 1905, of the same periodical, Maximilian Toch, Assoc. Am. Soc. C. E., comments on Mr. Hain's experiments, and says:

"We found that the disintegration [of the briquette immersed in signal oil] was due to the formation of oleate and stearate of calcium. To reduce this to its simplest expression, the animal oils contain acids

* *Engineering News*, March 16th, 1905.

which combine with the lime, and crystals of stearate and oleate of lime are formed. It is very likely that these crystals in the process of formation have increased the bulk in the briquette and the bond which has been formed by the lime in the set cement has been totally disintegrated and ruptured. Mr. Boucher.

* * * * * *

"Machinery oil which contains no animal fat is evidently harmless to cement concrete for the reason that no combination can occur. Machinery oils are almost exclusively paraffine oils."

A. T. Goldbeck,* Esq.—It is a peculiar thing that, with all the oils used in Mr. Page's experiments, the tensile strength of 1:3 mortar has been but very slightly affected by the oil admixture. In a great many instances the tensile strength even exceeds the strength of plain 1:3 mortar, although, at the same time, the crushing strength of concrete mixed with the same kinds of oils is invariably somewhat less than that of plain mixtures. Only one oil, thus far, has been found to affect the tensile strength seriously, and this oil perhaps more nearly resembles the asphaltic California products than any of the others used. Mr. Goldbeck.

As stated by Mr. Owen, the influence of lubricating oils on plain concrete foundations is, in a great many instances, very severe. Animal and vegetable oils disintegrate concrete, and many of the lubricating oils contain animal and vegetable oil admixtures. This disintegrating action is particularly severe on lean, absorbent mixtures which may take up a very large quantity of oil. The mineral oil concrete mixture must be regarded in a different light from that of a plain concrete subjected to the penetrating action of lubricating oils. It is true that a very large percentage of oil, when mixed with the wet concrete, will cause it to lose all strength, but such excessive admixtures are unnecessary as well as dangerous. A small percentage, however, of the right kind of oil seems to be of benefit as a damp-proofing agent, and does not seem to be dangerously detrimental to the strength of the mixture.

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MEMOIRS OF DECEASED MEMBERS.

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GEORGE EDWARD GRAY, Hon. M. Am. Soc. C. E.*

DIED JANUARY 1ST, 1913.

George Edward Gray, the son of Joel and Betsey R. Gray, was born at Verona, N. Y., on September 12th, 1818.

After receiving a public school education, he studied civil engineering under Pelatiah Rawson, a pioneer in the Profession in this country.

In August, 1839, Mr. Gray was appointed Resident Engineer on the Black River Canal, in New York State, and remained in that position until 1842. He then served as Assistant Engineer, under the late Allan Campbell, M. Am. Soc. C. E., Chief Engineer, and the late A. W. W. Evans, M. Am. Soc. C. E., Resident Engineer, on the New York and Harlem Railroad until 1847, when he returned to the Black River Canal, serving as Assistant Engineer and, later, as Resident Engineer, on that and the Erie Canal.

In the Spring of 1852, he was appointed Chief Engineer of the Utica and Schenectady and the Mohawk Valley Railroads, and, in 1853, when these and other roads were consolidated to form the New York Central Railroad, he was made Chief Engineer of the latter, remaining in that position until May, 1865. It was during his incumbency as Chief Engineer, and under his immediate direction, that the first wrought-iron truss bridges in the United States were built on the line of this railroad. He also acted as Chief Engineer on the construction of the Hudson River Bridge, at Albany, N. Y., from 1860 to May, 1865.

In 1865 Mr. Gray was made Consulting Engineer of the Central Pacific Railroad which, with the Union Pacific Railroad, completed the first transcontinental railroad in the United States. Mr. Gray continued in this position until 1871, when he was employed as Chief Engineer by the Southern Pacific Railroad, and in this capacity had charge of the construction of many miles of that road and of the various other railroads comprising the Southern Pacific System.

In 1885, he retired from railroad work and engaged in consulting practice at his home in Elmwood Park, Berkeley, Cal., until his death on January 1st, 1913.

Mr. Gray was held in affection and respect by all who knew him and his work. He was a member of many technical and scientific associations, including the Institution of Civil Engineers of Great

* Memoir prepared by the Secretary from material on file at the Society House.

Britain, the California Academy of Sciences, the San Francisco Association of the American Society of Civil Engineers, etc., and served as a Trustee of the Leland Stanford, Jr., University for many years.

Mr. Gray was elected a Member of the American Society of Civil Engineers on July 2d, 1873, and an Honorary Member on June 5th, 1894.

PETER SUTHER ARCHIBALD, M. Am. Soc. C. E.*

DIED MARCH 16TH, 1913.

Peter Suther Archibald, the son of William and Elizabeth (Blair) Archibald, was born at Truro, Nova Scotia, on March 21st, 1848, and received his education in the Truro Model and Normal Schools.

Mr. Archibald began his professional career as a Rodman on the preliminary surveys for the Intercolonial Railway in September, 1867, under *Sir* Sandford Fleming, M. Am. Soc. C. E., and, during the construction of the road and its subsequent operation, he rose, by sheer ability and application, from one position to another, until, in 1879, he became Chief Engineer of the railroad which, as a boy, he had helped to construct. This position he held until his resignation, in 1898, to take up private practice as a Consulting Engineer.

Mr. Archibald was Consulting Engineer of the St. John Cantilever Bridge and Railway Extension Company, by special permission of the Minister of Railways. In 1894 he was appointed a member of the Royal Commission to inquire into freight rates in Manitoba and the Northwest Territories.

In 1902 he was made Chairman of an Arbitration Tribunal between Contractor Reid and the Newfoundland Government, which involved a $2 000 000 claim; and, later, he was Chairman of the Arbitration Board to settle the question of the Newfoundland telegraph lines. He was also employed as an expert in disputed matters between the Clergue Syndicate and its contractors on railway construction.

In 1905 Mr. Archibald was Contractor's Engineer for Mr. A. E. Trites, on the construction of the Northern Maine Seaport Railroad, now a part of the Bangor and Aroostook Railroad. In 1907 he was appointed a member of the Conciliation Board *re* the Cumberland Coal and Railway Company, under the Industrial Disputes Act, and in 1908 he was made a Commissioner by the New Brunswick Government to manage the New Brunswick Central Railway.

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*Memoir prepared by William B. MacKenzie, Esq., Right-of-Way and Lease Agent, Intercolonial Railway of Canada, Moncton, N. B., Canada.

Mr. Archibald's capabilities as a Consulting Engineer were so widely recognized that, after taking up private practice, his services and advice were frequently sought in cases of special importance, as well as in many smaller projects for railways, bridges, and water supplies.

Mr. Archibald was a wide reader; a man of calm, even temperament, a true friend, and a gentleman who possessed the confidence and respect of those who had the pleasure of his acquaintance. By his ever-ready desire to assist those in need, he secured not only the respect of his professional brethren, but the admiration and loyalty of his subordinates.

In April, 1874, Mr. Archibald was married to Miss Clara G. Lindsay, the daughter of Mr. F. S. Lindsay, of Rockland, Me.

He was a Member and Councillor of the Canadian Society of Civil Engineers, and a Lieutenant in the 73d Volunteer Battalion.

Mr. Archibald was elected a Member of the American Society of Civil Engineers on January 7th, 1885.

PHILIP HENRY COOMBS, M. Am. Soc. C. E.*

Died March 6th, 1913.

Philip Henry Coombs, the son of P. H. and Sarah Forbes (Woodhull) Coombs, was born at Bangor, Me., on December 24th, 1856. He was educated in the public schools of that place, and in 1875 entered the office of his uncle, the late Frederick H. Coombs, who was then City Engineer of Bangor, as his Principal Assistant, remaining in this position until 1883.

In November, 1883, Mr. Coombs was elected City Engineer and Superintendent of Sewers of Bangor, which office he held continuously until March, 1893. He occupied the same office in 1894, 1899, and from 1901 to 1905, inclusive. He also served as City Engineer for Brewer, Me. During his incumbency as City Engineer, Mr. Coombs had charge of the construction of many miles of sewers, and thereby became an authority on the plan of the City of Bangor, its streets, and sewerage system, a knowledge which proved of great value during his long period of service as a public official.

As City Engineer, he also made the plans, specifications, and contracts, and had direct charge of the construction of the masonry pier and abutments for Kenduskeag Bridge in 1884 and 1889, and of the masonry pier for the Franklin Street Bridge, in 1885, this latter work

* Memoir prepared by the Secretary from material on file at the Society House.

having been done jointly by the United States Government and the City of Bangor. He also supervised the erection of the new steel bridge between Bangor and Brewer; the reconstruction and extension of the Bangor Water-Works; and the erection of the Eastern Maine Insane Hospital, as well as the construction of roads and the design of the landscape work.

In addition to the work done for the City of Bangor, Mr. Coombs made surveys and plans for water-works and sewerage systems in many other towns in Maine, including Dexter, Dover, Foxcroft, Newport, and Brewer.

In 1887, he formed a partnership with Thomas W. Baldwin, M. Am. Soc. C. E., under the firm name of Baldwin and Coombs. The firm was engaged in general engineering practice until 1892, when Mr. Baldwin removed from Bangor, and the business was taken over by Mr. Coombs.

Mr. Coombs was widely known as a Consulting Engineer, and had charge of the construction of many large industrial plants, including the pulp mills of the Penobscot Chemical Fibre Company, at Great Works, Me., in 1881-83; the paper and pulp mills of the Eastern Manufacturing Company, at Brewer, in 1889; the Orono Pulp and Paper Company, at Basin Mills, Orono, Me.; and the Webster Paper Company, at Orono, Me., in 1890.

In 1888, he had charge of laying out the Bangor Street Railway, the first electric road built in Maine, and one of the first to be operated successfully in the United States. He was also engaged as Engineer on the survey and construction of railroads of several companies centering in Bangor, from 1888 until his death.

In 1901, Mr. Coombs was one of two Commissioners, authorized by the Maine Legislature and appointed by the Penobscot Log Driving Company, on a survey of the West Branch water-shed of the Penobscot River to investigate and determine the present storage, and need of increased storage for log-driving, manufacturing, and other purposes. He remained in the service of the Penobscot Log Driving Company until his death, being engaged chiefly on hydraulic work.

Mr. Coombs was also employed at various times as Engineer in charge of the construction of Chapin Park, Broadway Park, and Summit Park, for the City of Bangor, and for a number of years he was also, as Engineer, in charge of the designs, plans, specifications, etc., of fishways for the Maine Fisheries Commission.

In January, 1883, Mr. Coombs was married to Miss Millie M. Field, of Bangor, Me., who, with two daughters, survives him.

On July 3d, 1911, he was suddenly stricken with what at first was thought to be sunstroke, but which later proved to be paralysis. He had partly recovered his health, and was able to attend to business,

but on March 2d, 1913, he had an attack of acute indigestion from which he died.

Mr. Coombs was a man of pleasant, genial disposition and had a wide circle of friends. He was especially prominent in Masonic affairs, and was also a member of the Order of Odd Fellows.

Mr. Coombs was elected a Member of the American Society of Civil Engineers on March 7th, 1906.

JAMES DIX SCHUYLER, M. Am. Soc. C. E.*

Died September 13th, 1912.

James Dix Schuyler was born at Ithaca, N. Y., on May 11th, 1849. He was the son of Philip Church and Lucy M. (Dix) Schuyler.

He received his early education at Friends' College which he attended from 1863 to 1868. He owed his high attainments in his Profession, and his versatility, very largely to subsequent study, a broad range of reading, and personal experience. As a young man he joined a railroad surveying party in Colorado, where he was stationed from 1869 to 1873, and, once imbued with the spirit of the West, he kept on to California where he made his home.

Mr. Schuyler began the practice of his Profession as Assistant Engineer on the location and construction of the Kansas Pacific Railway, in Western Kansas and Colorado, and was Resident Engineer on the last division of the road, remaining on this work until its completion in 1870. He was then appointed Resident Engineer on the Denver and Rio Grande Railroad, from Colorado Springs to Denver, and made the first survey of Colorado Springs. On arriving in California, in 1873, he was made Division Engineer of the North Pacific Coast Railroad from Ross Valley to San Rafael. In 1874 he was appointed Chief Engineer of the Stockton and Ione Railroad, and on the financial collapse of that project, he worked temporarily as a writer for the *Stockton Daily Independent*. In 1877 he was made Chief Assistant State Engineer, in the State Engineering Department of California, and was placed in charge of the irrigation investigations being conducted by that Department in the Great Central Valley of California.

Mr. Schuyler remained with the State Engineering Department until 1882, when he resigned to accept the position of Chief Engineer and General Superintendent of the Sinaloa and Durango Railroad in Mexico. In 1884 he returned to California, and was engaged for a time as a Contractor in the construction of a section of the sea-wall

* Memoir prepared by Stephen E. Kieffer, C. E. Grunsky, and J. B. Lippincott, Members, Am. Soc. C. E.

on the water-front of San Francisco. During the following year he was placed in charge of raising and completing the Sweetwater Dam, and the work which he did there assured his standing in the Engineering Profession, his rise to prominence thereafter being rapid.

Mr. Schuyler was called into conference and was placed in charge of important work in various parts of the United States and in Mexico. From 1891 to 1895 he was Consulting Engineer to the Lake Hemet Water Company, and designed and supervised the construction of the Hemet Dam, one of the highest masonry dams in Western America. He was engaged on the construction of water-works at Portland, Ore., and at Denver, Colo., on the Bear River Canal, in Utah, on the Ogden, Utah, Water-Works, and on irrigation works at various places in the West. He was one of the Board of Consulting Engineers to pass on the feasibility of the Owens River water-supply project, for Los Angeles, Cal., and was appointed by President Roosevelt as a member of the second Commission of Consulting Engineers which passed on the feasibility of the Gatun Locks, the Gatun Dam, and related structures for the Panama Canal.

His activities as a Consulting Engineer extended across the ocean to Japan, and as far south as Brazil. He was Consulting Engineer to the Territorial Government of Hawaii on the construction of the Nuuanu Dam; to the Monterey Water-Works and Sewer Company, Limited, of Mexico; to the Kobe Syndicate on an extensive power project in Japan, involving the construction of a very high dam; to the Mexican Light and Power Company, Limited, on the building of four large dams for power development in Mexico; to the Vancouver Power Company, Limited, on the building of a dam at Coquitlam Lake; to the Arrowhead Reservoir Company; the American Beet Sugar Company; and the Sweetwater Water Company.

Mr. Schuyler not only did much in a constructive way that will endure, but he had the happy faculty of imparting, through his writings, the results of his work and experience to other members of his Profession. Among engineers he was recognized as being unusually resourceful, and as having an unusual grasp on the experience of other members of the Profession, which he understood how to apply.

In writing of Mr. Schuyler and his work, Dr. George Wharton James says:

"His unfailing good humor, ready acquiescence in every experience, cheerful bearing of hardship, inconvenience, and annoyance, his uniform kindness, urbanity and courtesy, his gentle consideration for his associates, his companions, and the employees and helpers with whom he came in contact, his ready and quick response to every human and humane feeling and sentiment, his kinship with every living thing, whether of animal or plant life, his keen powers of observation and

far-reaching grasp of reflection, his tenacity of memory, and thorough conscientiousness in getting hold of every fact that would aid him in his decisions, his persistent questioning and careful recording of the results obtained, his joy in recognizing the possibilities of a great project, his ready acknowledgments of errors in judgment based upon imperfect knowledge, his eloquent and forceful presentation of facts as he saw them, the brilliant keenness of his intellect in dealing with knotty problems of his Profession, the far-seeing scope of his fine and trained imagination, his loyalty to his friends, his kind toleration of those who harshly differed from him, his open devotion, sincere admiration, and genuine affection for his wife, his brothers, his sisters, his family generally—these and a score of other traits clearly manifest in our association endeared him to me in a manner peculiarly potent.

"Physically, he was a large man, a man of impressive appearance, yet he was larger and more impressive mentally and spiritually than he was physically. A man of the keenest spiritual perceptions, he was yet a man among men, without a trace of the egotist or prig. His smile was an outward expression of a kindly, genial, humane nature. He wore no celluloid smile, formed by facial control. When his face beamed upon you it was the spontaneous, natural, ready response to the smile of his soul, warming you to trust, confidence, belief. He called forth the best of every man with whom he came in contact. He was a mental and spiritual dynamo, generating and radiating activity, peace, and good will to men.

"In his Profession he ranked with the highest and best, and at his funeral in Ocean Park, in September, every prominent member of the engineering and cognate professions of Southern California was present in person or by representative, and the expressions of the sense of loss were intimate and personal. The world has too few such men; would there were more."

In July, 1889, Mr. Schuyler was married to Mrs. Mary Ingalls Tulliper, of San Diego, Cal., who survives him.

He was a member of the Institution of Civil Engineers of Great Britain, the American Geographical Society, the Franklin Institute, the Technical Society of the Pacific Coast, and the Union League. He contributed extensively to various technical and scientific journals and Society publications, his best-known work being his book entitled "Reservoirs for Irrigation, Water Power, and Domestic Water Supply," which was first published in 1901, a second edition having been issued in 1908. He was twice winner of the Thomas Fitch Rowland Prize given by this Society for the best paper presented during the year, the first in 1889 for the paper "The Construction of the Sweetwater Dam,"* and the second in 1907 for his paper "Recent Practice in Hydraulic-Fill Dam Construction."†

* *Transactions*, Am. Soc. C. E., Vol. XIX, p. 201.

† *Transactions*, Am. Soc. C. E., Vol. LVIII, p. 196.

Mr. Schuyler was elected a Member of the American Society of Civil Engineers on December 6th, 1882. He also served as Vice-President in 1903-04, and as a Director in 1892, and from 1899 to 1901.

FRANK SOULÉ, M. Am. Soc. C. E.*

DIED FEBRUARY 14TH, 1913.

Frank Soulé was born at Woodville, Miss., on August 6th, 1845. He came from New England ancestry, being a descendant of the Mayflower Pilgrims, and tracing his lineage directly to John Alden, Priscilla Mullins, and George Soulé. His father, Frank Soulé, went to California in May, 1849, where, later, he was well known as a journalist and as one of the authors of the "Annals of San Francisco."

Professor Soulé received his early education at Bridge Hampton, N. Y., and at the San Francisco High School. In 1862 he was appointed to the United States Military Academy at West Point, from which he was graduated in 1866. Immediately thereafter, he was assigned to duty as Assistant Ordnance Officer. In 1868 he was ordered to West Point as Instructor in Ordnance and Gunnery, and also performed the duties of Assistant Professor of Mathematics.

In 1870 he resigned from the Army to join the Faculty of the University of California, as Assistant Professor of Mathematics. In 1872 the Board of Regents established the Department of Civil Engineering by creating a chair for that subject; and on the appointment of Professor Soulé to that chair, they added Astronomy to his responsibilities.

The records of the University of California for the period ending with 1880 will show how prominent was the work of Professor Soulé in those early days. He not only gave his time to Mathematics, Astronomy, and Engineering, but also organized the Military Department. In 1886 the Students' Astronomical Observatory was designed and built by him with special State appropriations. In the next ten years, under his direction and with the co-operation of the late Professor George Davidson, Hon. M. Am. Soc. C. E., many important geodetic studies were maintained and measurements made. He inaugurated the Weather Bureau Record, which later was distributed by the Department of Astronomy, and now is reported by the Department of Geography. In 1890, the exacting demands of the rapidly growing Civil Engineering College forced Professor Soulé to relinquish his interests in astronomical work, although he retained the title of Professor of Astronomy with that of Civil Engineering for several years afterward. In the early Nineties, after a visit to prominent Eastern and European schools, he built and equipped a testing laboratory which from a modest beginning has grown into the present Experiment Station of the Civil Engineering Department.

* Memoir prepared by C. Derleth, Jr., M. Am. Soc. C. E.

Professor Soulé continued in the active service of the University as Professor of Civil Engineering and as Dean of the College of Civil Engineering until the summer of 1907, a period of 38 years. In 1907 he spent a sabbatical year in foreign travel, visiting Egypt and most of the countries of Europe. On his return to California in 1908, he was retired on the Carnegie Foundation, becoming Professor Emeritus of Civil Engineering. Although his active work had ceased, he still retained a deep interest in the welfare and rapid growth of the College which he had organized. It is given to few men to serve an institution for a span of 44 years and in such varied capacities.

He was a man of multifarious tasks and of many-sided usefulness. No one was in closer touch with the students than he, both by virtue of his one-time office as Commandant of the Cadets and by the nature of his own interests. He was a military man in bearing and in thought, and believed in discipline and in authority. He laid upon himself the heavy hand of self-control, but was always kindly toward and thoughtful of others, and, above all things, was a man of unfailing courtesy.

During the last ten years of his service, it was his deserved pleasure to witness the great expansion of the Engineering Colleges of the University. From 1870 to 1900 his school, like San Francisco, developed slowly. It was about 1895 that, as a University, California began to grow with leaps and bounds. In his immediate Civil Engineering College a Department of Irrigation was established; courses relating to Forestry and Public Health were planned; and the relations between Agriculture and Engineering were defined. Sanitary studies formed a vital part of the curriculum, and instructors in Municipal and Sanitary Engineering were called to co-operate with the Medical Department in Bacteriology, Animal Industry, and Hygiene. In Civil Engineering there is now close contact between the sanitary instructors and the interests of the University known as Domestic Science. The Professors of Sanitation and Irrigation are concerned with the practical Agricultural School at Davis. The Structural Departments are associated with Architecture, no less than with Engineering. The Testing Laboratory is in touch with State problems. Surveying courses lead to instruction in Geodesy, through which channel the students are brought in contact with the Department of Astronomy. Through railroad work they deal with Economics; by the writing of contracts and specifications they lean on the Law; in the design of buildings they become interested in fire-proof construction, fire protection, and prevention, and are led to commune with the Departments of Economics and Insurance. All these relationships now exist, are daily developing, and are bringing Civil Engineering into closer sympathy and bond with the University. Professor Soulé served his University for 44 years; he saw it start from the humblest beginning, and witnessed its growth into one of the most powerful institutions in the country, a University

which, in 1913, is second in numbers in the United States. Moreover, as an Instructor in Engineering he lived through those eventful years in the development of Engineering Education—from the pioneer days of instruction in Applied Science to the present decade of great promise.

Professor Soulé was always interested in the public affairs of the community in which he lived. Whenever a movement looking to a betterment in politics and community life developed in California in recent years, that movement found in him a ready helper. In earlier days his active interest was in Oakland; later, this was transferred to Berkeley, where he was a member of the Committee which framed the now famous New Charter for that city. He was an active member of the City Club of Berkeley, and often presided and spoke at citizens' meetings.

As Professor Soulé gave much of his energy and life to community interests and problems, it was only natural that he should be associated with many societies. He was a member of the Association of Graduates of the U. S. Military Academy, and of the Loyal Legion, U. S. A.; Colonel in the National Guard; life member of the Geographical Society of the Pacific; member of the Society of Mayflower Descendants; and life member of the Society of California Pioneers. For many years he was a member of the Athenæn Club of Oakland, and of the University Club and the Bohemian Club of San Francisco.

Professor Soulé did not practice continuously his Profession as a Designing and Consulting Engineer; he was too busy with educational and social tasks, as already stated. Nevertheless, for thirty years he was a force in Engineering circles in the State of California, often serving in an advisory capacity or as a Consulting Engineer. He was a judge of materials and their tests, and frequently reported on road, street, sewer, and water supply projects for Berkeley, Oakland, and other growing towns and cities. Perhaps his most important reports were those which related to irrigation studies in the San Joaquin Valley and to the difficult foundation problems for the Perry Building and adjoining docks in San Francisco.

He is survived by his widow, Mrs. Adelaide S. Soulé, and two sons.

Professor Soulé was elected a Member of the American Society of Civil Engineers on March 1st, 1905.

ARTHUR GARFIELD CRYSLER, Assoc. M. Am. Soc. C. E.*

Died October 22d, 1912.

Arthur Garfield Crysler, the son of George and Harriet (Safford) Crysler, was born at Syracuse, N. Y., on April 24th, 1880. After going through the graded schools and the Syracuse High School, he

*Memoir prepared by Guy Moulton, M. Am. Soc. C. E.

entered Syracuse University in 1900, and was graduated in 1904, with the degree of C. E.

Immediately after his graduation, Mr. Crysler entered the service of New York State as Rodman in the Department of the State Engineer and Surveyor. He was assigned to work on the preliminary surveys, plans, and estimates of Contract No. 12, of the Barge Canal. In 1907 he was made Assistant Engineer and placed temporarily in charge of that portion of Contract No. 12 between Brewerton and Three Rivers, on the Oneida River, 12 miles of heavy work, including one lock. He did so well that the temporary appointment was made permanent, and he was in charge of the work at the time of his death.

On June 26th, 1906, Mr. Crysler was married to Miss Pearl LaShier, of Ithaca, N. Y., who, with three children, survives him.

Mr. Crysler was elected Associate Member of the American Society of Civil Engineers on August 31st, 1909. He was also a member of the Technology Club of Syracuse, N. Y.

STEPHEN HOLMAN, F. Am. Soc. C. E.*

Died October 13th, 1912.

Stephen Holman was born at Royalston, Mass., on December 28th, 1820. He was the son of Stephen and Hannah (Fuller) Holman whose ancestors settled at Newburyport, Mass., early in the Eighteenth Century, several having served in the War of the Revolution.

On the death of his father in 1832, the boy went to live with his half-brother at Saugus, Mass. After attending school at Saugus Centre, he entered the Lynn Academy where he prepared for college. He was graduated from Williams College in the Class of 1840. Afterward, he studied law and was admitted to the bar, but never practiced that profession to any extent, preferring that of teaching. For a number of years he served as principal of high schools and academies at Winchester, N. H., Gardner, Athol, Phillipston, Fitchburg, and Holyoke, Mass.

While in the latter city Mr. Holman was employed as Paymaster at the Lyman Mills, and, in 1860, bought a controlling interest in the Holyoke Paper Company, which he managed with conspicuous ability. In 1865 he sold his interest in that Company and established the Holyoke Machine Company, and, later, a branch of the same company at Worcester, Mass. He also founded the Deane Steam Pump Company, of Holyoke, and became interested in a number of cotton mills and also in the American Telephone Company.

* Memoir prepared by the Secretary from information supplied by C. J. H. Woodbury, M. Am. Soc. C. E.

Mr. Holman was very successful in business, and this success was due in part to his power of initiation. He was the originator of many new methods of reducing business to a scientific basis, and was the first to establish the present methods of cost-keeping in paper mills. An example of his original methods was the establishment of a testing flume at the works of the Deane Steam Pump Company, at Holyoke, by which every water-wheel manufactured at the plant could be tested, as to head and power, under actual service conditions, thereby guaranteeing them to purchasers. This flume was also placed at the disposal of any manufacturer who cared to make use of it for testing.

Mr. Holman retained his physical and mental vigor until his death, keeping in close touch with his business interests. He was a student and an accomplished linguist, never losing touch with his college studies, especially that of the German language and literature of which he was particularly fond. At the age of ninety he gave a reading from Schiller's plays before a German association.

He was a brilliant conversationalist, and, having a wonderful range of general knowledge, could entertain others no matter what their tastes and experiences in life had been. He was tenacious in his friendships, particularly with men, his cultured mind and strength of intellect making him a dominating figure in personal associations and in business life.

Fondness for Nature was one of Mr. Holman's strong characteristics, which was gratified by extensive travel in this country and in Europe. He had just returned from a European trip when he was seized with a sudden attack of neuralgia of the heart which caused his death at Swampscott, Mass.

On April 12th, 1853, Mr. Holman was married to Miss Hannah A. Richardson, of Lowell, Mass., who died in 1894. He is survived by a son and a daughter.

He was a Member of the Mt. Tom Lodge, A. F. and A. M., and of many other organizations. At the time of his death he was the oldest Alumnus of the Lynn Academy and of Williams College. He was also the Senior Mason and the Senior Member of the Massachusetts bar.

Mr. Holman was elected a Fellow of the American Society of Civil Engineers on June 29th, 1872.

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William P. Morse

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LINCOLN BUSH	JAMES H. EDWARDS	J. WALDO SMITH
GEORGE C. CLARKE	ROBERT RIDGWAY	CHARLES D. MARX
HENRY W. HODGE	CHARLES S. CHURCHILL	T. KENNARD THOMSON
LEONARD METCALF	WILLIAM CAIN	E. C. LEWIS
EMIL GERBER	JONATHAN P. SNOW	CHAS. WARREN HUNT

Special Committees

ON CONCRETE AND REINFORCED CONCRETE: Joseph R. Worcester, J. E. Greiner, W. K. Hatt, Olaf Hoff, Richard L. Humphrey, Robert W. Lesley, Emil Swensson, A. N. Talbot.

ON ENGINEERING EDUCATION: Desmond FitzGerald, Onward Bates, D. W. Mead.

ON STEEL COLUMNS AND STRUTS: Austin L. Bowman, Emil Gerber, Charles F. Loweth, Ralph Modjeski, Frank C. Osborn, George H. Pegram, Lewis D. Rights, George F. Swain, Emil Swensson, Joseph R. Worcester.

ON BITUMINOUS MATERIALS FOR ROAD CONSTRUCTION: W. W. Crosby, A. W. Dean, H. K. Bishop, A. H. Blanchard.

ON VALUATION OF PUBLIC UTILITIES: Frederic P. Stearns, H. M. Byllesby, Thomas H. Johnson, Leonard Metcalf, Alfred Noble, William G. Raymond, Jonathan P. Snow.

TO INVESTIGATE CONDITIONS OF EMPLOYMENT OF, AND COMPENSATION OF, CIVIL ENGINEERS: Alfred Noble, S. L. F. Deyo, Dugald C. Jackson, William V. Judson, George W. Tillson, C. F. Loweth, John A. Bensel.

TO CODIFY PRESENT PRACTICE ON THE BEARING VALUE OF SOILS FOR FOUNDATIONS, ETC.: Robert A. Cummings, Edward C. Shankland, Edwin Duryea, Jr., James C. Meem, Walter J. Douglas, Samuel T. Wagner, Frank M. Kerr.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

TELEPHONE NUMBER....................5913 Columbus.
CABLE ADDRESS.........................."Ceas, New York."

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AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PROCEEDINGS

This Society is not responsible for any statement made or opinion expressed in its publications.

SOCIETY AFFAIRS

CONTENTS

MINUTES OF MEETINGS

OF THE SOCIETY

May 21st, 1913.—The meeting was called to order at 8.30 P. M.; Vice-President J. Waldo Smith in the chair; Charles Warren Hunt, Secretary; and present, also, 89 members and 15 guests.

A paper by John R. Nichols, Jun. Am. Soc. C. E., entitled "Statical Limitations Upon the Steel Requirement in Reinforced Concrete Flat Slab Floors," was presented by the author, who illustrated his remarks with lantern slides.

The Secretary read communications on the subject from Messrs. L. J. Mensch, C. A. P. Turner, H. T. Eddy, and Edward Godfrey, and the paper was discussed orally by Messrs. W. W. Crehore, A. W. Buel, E. S. Martin, and the author.

A paper by Dunbar D. Scott, M. Am. Soc. C. E., entitled "Recent Improvements in Leveling Instruments," was presented by title only.

The following resolution was presented by the Secretary in behalf of W. P. Darwin, Assoc. M. Am. Soc. C. E.:

"*Moved:* That this Society appoint a committee of five to prepare an Ideal Building Code to govern the general and essential features of construction of buildings in our American cities."

On motion, duly seconded, the resolution was referred to the Board of Direction.

The Secretary announced the following deaths:

Adolphus Bonzano, elected Member, August 7th, 1872; died May 5th, 1913.

Samuel Lispenard Cooper, elected Member, February 6th, 1889; died May 8th, 1913.

William Napier Radenhurst, elected Junior, July 7th, 1875; Member, July 7th, 1880; date of death unknown.

Robert Wilson Sayles, elected Associate Member, April 5th, 1905; Member, May 5th, 1908; died May, 1913.

Adjourned.

June 4th, 1913.—The meeting was called to order at 8.30 p. m.; Vice-President J. Waldo Smith in the chair; Chas. Warren Hunt, Secretary; and present, also, 140 members and 12 guests.

The Secretary announced that a Philadelphia Association of Members of the American Society of Civil Engineers had been formed, with the approval of the Board of Direction.

The Secretary announced that the Board of Direction had decided to appoint a Special Committee to investigate the advisability of drafting a National Water Law,* and also a Special Committee to study the question of Floods, Flood Prevention, and other Allied Subjects.†

The Secretary announced that the Board of Direction had considered the matter of the appointment of a committee to prepare an Ideal Building Code, but deemed it inadvisable to appoint such a committee.‡

The following motion was offered by J. P. Snow, M. Am. Soc. C. E.: "That it is the sense of this meeting that the American Society of Civil Engineers should appoint a Special Committee to act jointly with the American Railway Engineering Association in studying and experimenting on the stresses in railroad rails, ties, etc."

The motion, being duly seconded, was carried.

Mr. Snow moved, further:

"That the matter of appointing this Committee be left with the Board of Direction with full power."

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* See page 417.

† See page 417.

‡ See page 417.

This motion, being duly seconded, was carried.

A paper by Samuel Tobias Wagner, M. Am. Soc. C. E., entitled "The Elevation of the Tracks of the Philadelphia, Germantown and Norristown Railroad, Philadelphia, Pa.," was presented by the author and illustrated with lantern slides. The paper was discussed by Messrs. J. P. Snow, E. W. Lewis, E. J. Rights, C. R. Harte, and the author.

On motion, owing to the lateness of the hour and the absence of the author, the paper entitled "The Philosophy of Engineering," by Maurice G. Parsons, Jun. Am. Soc. C. E., was not read, but was presented by title only. The Secretary read communications on the subject from Messrs. Lewis M. Haupt, Charles Kirby Fox, A. H. Markwart, and Morgan Cilley.

The Secretary announced the election of the following candidates on June 4th, 1913:

As Members

George Harmon Bayles, Dobbin, W. Va.
Horatio Bevan Bowerman, Baltimore, Md.
Edgar Dudley Cruise, Ashton, Idaho
Thurston Carlyle Culyer, Purdy Station, N. Y.
Charles Frommer, Philadelphia, Pa.
Henry Stuart Johnson, Honolulu, Hawaii
George Clark Mills, Rochester, N. Y.
Juan Real y Gaillard, Santiago de Cuba, Cuba
Charles Montieth Redfield, Des Chutes, Ore.
John McClure Salmon, Louisville, Ky.
Ferdinand Emil Toenniges, Cambridge Springs, Pa.
John Abbet Walls, Baltimore, Md.
Cyril Williams, Jr., San Francisco, Cal.

As Associate Members

Daniel Wesley Albert, Juab, Utah
Clarence Nully Black, Beaumont, Tex.
William Harris Boardman, Newark, N. J.
Haig Milton Boyajohn, Portland, Ore.
Barnett Braslow, New York City
James Gregory Brennan, Albany, N. Y.
John Maughs Brown, Vermilion, S. Dak.
Eugene Burnell, New York City
Philip Chapin Davis, Bridgeport, Conn.
Frank Warwick Decker, Manila, Philippine Islands
Charles Edwin Dexter, White Sulpher Springs, W. Va.
Harry Henry Frost, Akron, Ohio
Chester Francis Gailor, Hartford, Conn.
George Augustus Graves, Trenton, N. J.
Russell de Costa Greene, Knoxville, Tenn.

Jules Edmond Hanique, East Auburn, Cal.
Clarence Haller Harlan, Millvale, Pa.
Benjamin Franklin Heidel, Washington, D. C.
Herbert Davis Hinman, Corozal, Canal Zone, Panama
Joel Manning Howard, Watertown, N. Y.
John Patrick Hurley, Brooklyn, N. Y.
Jacob Louis Jacobs, Chicago, Ill.
Percy John Jennings, Calgary, Alberta, Canada
Edward Dyer Kingman, East Lansing, Mich.
Roy Alton Klein, Orenco, Ore.
James Duncan Knapp Lyman, Mt. Vernon, Ohio
Hugh Miller, Potsdam, N. Y.
Edwin Thaddeus Albinus Morris, New York City
Michael Joseph O'Hara, Hudson, N. Y.
Carey Simon Pratt, Urbana, Ohio
George William Rathjens, St. Paul, Minn.
Warner Irelan Risley, Atlantic City, N. J.
Lyman Chambers Shank, Cleveland, Ohio
Herbert James Smith, East Haddam, Conn.
Frederick Spengler, Spokane, Wash.
Edward Ahlert Stuhrman, Brooklyn, N. Y.
Hubert Southwick Tullock, Leavenworth, Kans.
James Thompson Wardlaw, Atlanta, Ga.
Robert Culin White, Wynne, Ark.
Edward Charles Wild, Chicago, Ill.

As Juniors

William Selby Allan, Chicago, Ill.
Charles Benjamin Brush, New York City
Norman Arthur Deiser, Brooklyn, N. Y.
John Robert Haswell, Easton, Md.
Charles William Gräbe Haydock, Philadelphia, Pa.
Arcadius Lars Peter Johnson, New York City
John Arthur Kelly, Keokuk, Iowa
Charles Lysander Rakestraw, Berkeley, Cal.
William Walker Ruggles, Seattle, Wash.
Carl Edward Sandstedt, Kahului, Maui, Hawaii
Archie Merle Truesdell, Vancouver, B. C., Canada

The Secretary announced the transfer of the following candidates on June 4th, 1913:

From Associate Member to Member

William Wesley Amburn, Portland, Ore.
Edward Smith Cole, New York City
Walton Pruett Darwin, Jacksonville, Fla.

Leonard Smith Doten, Washington, D. C.
John Duder, Salt Lake City, Utah
John Howell Griffith, Pittsburgh, Pa.
Howard Benson Wilberforce Howie, Chattanooga, Tenn.
William Henry Insley, Indianapolis, Ind.
Maurice Joseph Leahy, Powell River, B. C., Canada
George Nathan Mitcham, Auburn, Ala.
Howard Cawthorne Phillips, Chicago, Ill.
Arthur Henry Pratt, White Plains, N. Y.
Hermann Victor Schreiber, Philadelphia, Pa.
Charles Joseph Tilden, Ann Arbor, Mich.
Herbert Joseph Wild, Chester, Pa.

From Associate to Member

John Coffee Hays, Visalia, Cal.

From Junior to Associate Member

Claude Isaac Auten, Lewiston, Me.
George Earle Burnham, Manila, Philippine Islands
John Richard Cahill, San Francisco, Cal.
Henry William Corp, Manila, Philippine Islands
Pinkney Edward Cunningham, Vicksburg, Miss.
Edgerton Chester Garvin, Augusta, Ga.
Chester Mason Gould, Cold Spring, N. Y.
Milo Clinton Halsey, Monrovia, Cal.
Alexander Sydney Lynch, Stamford, Conn.
William Clyde Willard, Oakland, Cal.

The Secretary announced the death of Horace Theophilus Herrick, elected Member, October 29th, 1912; died May 26th, 1913.

Adjourned.

FORTY-FIFTH ANNUAL CONVENTION, HELD IN OTTAWA, ONT., CANADA, JUNE 17TH-20TH, 1913

FIRST SESSION *

Tuesday, June 17th, 1913.—The first session of the Convention was opened at the Chateau Laurier at 3 P. M.; C. H. Keefer, M. Am. Soc. C. E., Chairman of the Joint Committee of members of the Canadian and American Societies and also Chairman of the Local Committee, introduced the Hon. Martin Burrell, Minister of Agriculture for Canada, and His Worship, Mayor Ellis, of Ottawa. These gentlemen addressed the meeting and welcomed the members to the Dominion of Canada and the City of Ottawa. George F. Swain, President, Am. Soc. C. E., replied on behalf of the Society.

Adjourned.

SECOND SESSION

Wednesday, June 18th, 1913.—The meeting was called to order at 10 A. M.; President George F. Swain in the chair; Chas. Warren Hunt, Secretary; and present, also, about 150 members and guests.

The President delivered the Annual Address.†

Adjourned.

THIRD SESSION, BUSINESS MEETING ‡

Wednesday, June 18th, 1913.—Immediately after the President had delivered the Annual Address, the Business Meeting was called to order by the President.

The Secretary presented a report on the suggestions of members as to the Time and Place for holding the Annual Convention of 1914.§

The Secretary also presented a letter from C. C. FitzGerald, M. Am. Soc. C. E., inviting the Society to hold its next Annual Convention in Havana, Cuba.||

On motion, duly seconded, the matter of the selection of the Time and Place for holding the next Annual Convention was referred to the Board of Direction, with power.

The Secretary presented a report of the Board of Direction on "Improvement in the Methods of the Presentation of Papers."¶

The Secretary presented a proposed amendment to Article VII of the Constitution.**

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*The report in full of this meeting is on page 419.

†See page 1237 of Papers and Discussions.

‡For the Report in Full of the Business Meeting, see page 423.

§See page 424.

||See page 425.

¶See page 429.

**See page 430.

On motion, duly seconded, it was decided to consider the two proposed amendments to Article VII separately.

On motion, duly seconded, the meeting expressed its approval of Section 1, Article VII, of the proposed amendment.

The Secretary read the second proposed amendment to Article VII of the Constitution.*

On motion, duly seconded, the whole matter of the proposed amendments to Article VII of the Constitution was referred to a committee of five to be appointed by the President.

The Secretary read a proposed amendment of Articles V and VI of the Constitution.†

The Secretary also read a communication on the subject signed by a large number of members.‡

On motion, duly seconded, the proposed amendments to Articles V and VI, together with the communication read by the Secretary, were referred to the committee to be appointed by the President to consider the proposed amendments to Article VII.

The Secretary announced that a Philadelphia Association of Members of the American Society of Civil Engineers had been formed, and that its Constitution had been approved by the Board of Direction.

The Secretary announced that the Board of Direction had decided to appoint a Special Committee to investigate the advisability of drafting a National Water Law applicable to all navigable, interstate, and other waters within the jurisdiction of the United States, and embracing all uses of water, etc., and would take up the matter in the near future.

The Secretary also announced that the Board of Direction had decided to appoint a Special Committee to study the question of Floods, Flood Prevention, and other allied subjects, and would take up the matter in the near future.

The Secretary announced that the Board of Direction had decided that "it is not advisable to appoint a Special Committee to prepare an Ideal Building Code to govern the general and essential features of construction of buildings in our American Cities."

The Secretary reported that the Board of Direction now had under consideration the question of the appointment of a Special Committee to act jointly with the American Railway Engineering Association in studying, and experimenting on, the stresses in railroad rails, ties, etc.

The Secretary presented a communication from Percival M. Churchill, Assoc. M. Am. Soc. C. E.§

On motion, duly seconded, the communication was referred to the Board of Direction.

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*See page 433.

†See page 442.

‡See page 443.

§See page 451.

The Secretary made a brief announcement in reference to the International Engineering Congress to be held in connection with the Panama-Pacific International Exposition in 1915 in San Francisco.

Adjourned.

ELECTIONS AND TRANSFERS BY THE BOARD OF DIRECTION, JULY 2D, 1913

Elected as Members

James Hobart Allport, Barnesboro, Pa.
Sherwood Alfred Cheney, San Francisco, Cal.
Wayne Almon Clark, Duluth, Minn.
Felix Ferras, São Paulo, Brazil
Albert Claude Hobart, New York City
Ralph Hills Howard, Jackson, Miss.
Lewis Abner Howland, Far Rockaway, N. Y.
Hurd Clarence Hurd, Barcelona, Spain
William Simpson Keller, Montgomery, Ala.
Dorsey Julian Parker, Birmingham, Ala.
Jasper Marion Phillips, Mondak, Mont.
Frederick Jarrett Reinke, St. Louis, Mo.
John Thomas Simpson, Newark, N. J.
Lloyd Duvall Smoot, Jacksonville, Fla.
James Theodore Voshell, Washington, D. C.
Osmar Lysander Waller, Pullman, Wash.
Philip Ridsdale Warren, Montreal, Que., Canada

Elected as Associate Members

Augustus Waterous Agnew, Prince Rupert, B. C., Canada
Francis Cyrus Bagby, St. Louis, Mo.
Albert Ross Bailey, Ann Arbor, Mich.
John Cecil Black, Los Angeles, Cal.
Robert Alexander Black, Quebec, Que., Canada
Clarence Morrison Brooks, Keene, N. H.
Oscar Harold Bundy, Washington, D. C.
George Hitchell Bunker, East Boston, Mass.
Charles Edward Cate, Empalme, Sonora, Mexico
Abraham Burton Cohen, East Orange, N. J.
Robert Mavin Cooksey, Baltimore, Md.
George Evelyn Doyen, New York City
Bjarne Nicolas Folling, Dallas, Tex.
Charles Worthington Fowler, San Juan, Porto Rico
Harvey Lockhart Handley, Yankee, N. Mex.
William Glenn Hoyt, St. Paul, Minn.

Frederick Brice Irvine, St. Marc, Haiti
Edwin Warley James, Washington, D. C.
Lee Morgan Jones, Port Arthur, Ont., Canada
Ernest William Kohl, Jr., Santiago de Cuba, Cuba
Carl Armor McClelland, Milner, Idaho
James Joseph Murphy, Detroit, Mich.
Charles Lawson Patterson, Pueblo, Colo.
Robert William Pommerer, New York City
Cecil Latta Reid, Fredericksburg, Va.
Claud Russell, Cebu, Philippine Islands
Verney Warren Russell, Cody, Wyo.
John Archibald Shaw, Manila, Philippine Islands
Roe Loomis Stevens, Seattle, Wash.
John Dickson Stevenson, Pittsburgh, Pa.
Herman Otto Weiss, Washington, D. C.
Oscar Frederick Wodrich, Minneapolis, Minn.
Frederick Calhoun Wyse, Columbia, S. C.

Elected as Associate

Nathan Chamberlain Rockwood, Brooklyn, N. Y.

Elected as Juniors

Stanley James Clausen, St. Louis, Mo.
Ralph Moses Gray, Sacramento, Cal.
Charles Sumner Heidel, Helena, Mont.
Harold Joseph Horan, St. Louis, Mo.
Bennett Kaminsky, Indianapolis, Ind.
Fred Roy Krach, Rock Island, Ill.
John Owen Miller, Palo Alto, Cal.
Clarence Edgar Morrow, Boston, Mass.
Charles Douglas Yelverton Ostrom, San Francisco, Cal.
Alston Orange Rose, Hilo, Hawaii
Joseph Rose, New York City
George Sampson Squibb, Brookline, Mass.
James Robert Stewart, Kansas City, Mo.
James Joseph Tobin, Boston, Mass.

Transferred from Associate Member to Member

Wilfred Keefer Barnard, Alhambra, Cal.
Paul Beer, Des Moines, Iowa
Gurdon Gilmore Black, St. Louis, Mo.
Lowell Edwin Conrad, Manhattan, Kans.
William Henry Gravell, Philadelphia, Pa.
Louis Wells Hall, Portland, Ore.
George Arthur Johnson, New York City

Charles Patterson McCausland, Hagerstown, Md.
Langdon Pearse, Chicago, Ill.
Anton Schneider, Chicora, Fla.
Clifford Milton Stegner, Cincinnati, Ohio
Frederick Eugene Turneaure, Madison, Wis.
William D Wiggins, Decatur, Ill.

Transferred from Junior to Associate Member

Frederick William Doolittle, Madison, Wis.
John Kramer Flick, Loch Raven, Md.
John Strider Hess, San Francisco, Cal.
Donald Winthrop Howes, Brooklyn, N. Y.
William Mahone, Jr., Norwood, N. C.
Walden LeRoy Malony, Spokane, Wash.
Walter Smyth Moore, Versailles, Ky.
Edgar Kingsbury Ruth, Cincinnati, Ohio
George Schobinger, Yuma, Ariz.
Nelson Taylor, Los Angeles, Cal.
Benjamin Franklin Vandervoort, Niagara Falls, N. Y.
Edward von Geldern, Yuba City, Cal.

OF THE BOARD OF DIRECTION

(Abstract)

June 4th, 1913.—President Swain in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Bush, Cain, Churchill, Clarke, Edwards, Endicott, Hodge, Metcalf, Ridgway, Smith, Snow, Staniford, and Thomson.

A Report of the Board on Improvement in Method of Presentation of Papers was adopted for presentation to the Annual Convention.*

A proposed Constitution of the Philadelphia Association of Members of the American Society of Civil Engineers was formally approved by the Board.

The following Resolution which was referred by the Meeting of the Society, May 7th, 1913, to the Board was considered:

"*Moved:* That the Board of Direction of the American Society of Civil Engineers be and is hereby authorized and directed to appoint a Special Committee to investigate the advisability of drafting a National Water Law applicable to all navigable, interstate and other waters within the jurisdiction of the United States, and embracing all uses of water, and that such Committee be directed to prepare a preliminary draft of such a law for submission at some regular meeting of the Society, if, in their judgment, it appears advisable."

It was moved, seconded, and carried, that it is the sense of this Board that such a Committee be appointed as soon as possible.

The President was requested to appoint a Committee of three members of the Board to select candidates for appointment on this Committee, and to report back to the Board.

The following Resolution which was referred by the Meeting of the Society, May 7th, 1913, to the Board was considered:

"*Resolved:* That the Board of Direction consider the matter of the appointment of a Special Committee to Study the Question of Floods, Flood Prevention, and other allied subjects."

It was moved, seconded, and carried, that it is the sense of this Board that such a Committee be appointed as soon as possible.

The President was requested to appoint a Committee of three members of the Board to select candidates for appointment on this Committee, and to report back to the Board.

The following Resolution which was referred by the Meeting of the Society of May 21st, 1913, to the Board:

"*Resolved:* That this Society appoint a Committee of five to prepare an Ideal Building Code to govern the general and essential features of construction of buildings in our American Cities."

It was moved, seconded, and carried, that it is the sense of the Board that a Special Committee to Prepare an Ideal Building Code as called for in the Resolution be not appointed.

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*See page 429.

It was ordered that a meeting of the Board be held on July 2d, 1913, for the sole purpose of canvassing Membership Ballots and taking action on applications for admission.

Ballots for membership were canvassed, resulting in the election of 13 Members, 40 Associates Members, 11 Juniors, and the transfer of 10 Juniors to the grade of Associate Member.

Fifteen Associate Members and 1 Associate were transferred to the grade of Member.

Applications were considered, and other routine business transacted.

Adjourned.

June 17th, 1913.—The Board met at the Chateau Laurier, Ottawa, Ont., Canada, during the Annual Convention, as required by the Constitution; President Swain in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Bates, Bensel, Clarke, Endicott, Leonard, Metcalf, Ockerson, Ridgway, Smith, and Thomson.

Several informal reports as to progress in matters relating to the Society work were received.

Adjourned.

July 2d, 1913.—A Special Meeting of the Board to canvass ballots and to consider applications for membership was held, Director George C. Clarke in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Edwards, Endicott, Gerber, Hodge, Leonard, Metcalf, and Ridgway.

Ballots for membership were canvassed resulting in the election of 17 Members, 33 Associate Members, 1 Associate, and 14 Juniors, and the transfer of 12 Juniors to the grade of Associate Member.

Thirteen Associate Members were transferred to the grade of Member.

Applications for membership were considered.

Adjourned.

REPORT IN FULL OF THE FIRST AND SECOND SESSIONS AND OF THE BUSINESS MEETING OF THE FORTY-FIFTH ANNUAL CONVENTION, OTTAWA, ONTARIO, CANADA.

FIRST SESSION

Tuesday, June 17th, 1913.—The Forty-fifth Annual Convention of the American Society of Civil Engineers opened at the Chateau Laurier at 3 P. M.

C. H. KEEFER, M. AM. SOC. C. E.—Ladies and Gentlemen, as Chairman of the Joint Committee of members of both the American and Canadian Societies, and also Chairman of the Local Committee of the American Society, the pleasant duty devolves on me of introducing to you the gentlemen who will extend their welcome to Canada and to Ottawa, the Honorable Martin Burrell, representing the Dominion Government, and His Worship, Mayor Ellis, representing the City of Ottawa. We all know, as engineers, that engineers are not speakers; we are more accustomed to do things. Therefore, I shall not take up your time, but shall introduce Mr. Burrell.

THE HON. MARTIN BURRELL (Minister of Agriculture for Canada).—Mr. President, I regret that business in Halifax makes it impossible for the Prime Minister to be here to-day. I wish to extend to you, on his behalf and for the Government, the heartiest welcome to Ottawa. Addresses of Welcome.

The American Society of Civil Engineers, including, as I understand, over seven thousand members, is one which would have a hearty welcome anywhere. In our own great country we have already achieved much notable engineering work, with which many of you are familiar. We have spanned mighty rivers and have many more to span. There are mountains to be pierced, canals to be extended and constructed, and still, in spite of what has already been done, large questions of transportation to deal with; it is obvious, therefore, that work such as yours must necessarily be of immense importance to members of a Government, who, after all, are trustees for the people, charged with the duty of seeing that the people's heritage is wisely developed on sound and permanent lines. Thrice welcome, therefore, to men like yourselves who do things.

My department is, perhaps, less associated with engineering work than many others, yet in the important matter of irrigation works, I need hardly point out to you the intimate relationship of engineering to agriculture. What Sir John Aird did in Egypt by the application of high engineering skill, in bringing vast areas of arid or semi-arid lands into fertility, you are doing in your own country, as we are, in a smaller way, in our own, and the supreme test of your work—as of the work of those who labor in other fields—must be, after all, what service it renders to humanity.

dresses of Welcome (continued). Frankly, I must confess an encyclopædic ignorance of engineering, notwithstanding, on the important side of my family, I may claim a somewhat intimate relationship to the engineering world. My wife's father commenced his long and distinguished career as an engineer by working on the Stockton and Darlington Railway—the first steam railway ever built. He had a vivid recollection of George Stephenson, who, on many occasions, placed his hands on the young lad's head. To those of you who are fathers I need hardly say that her father's hands were often placed upon my wife's head, and to those of you who are husbands I can appeal for sympathy and support in saying that my wife's hands have often been placed on my head. This surely then would be an apostolic succession which ought to enable me to pass muster before this gathering.

We are glad to see you here at Ottawa, the home of the only man outside your own country whom you have made President of your Society. It was in 1888 that Thomas C. Keefer was elected President of the American Society of Civil Engineers. He is happily with us yet, at a ripe old age, surrounded by a family several of whom have achieved distinction in the engineering world, comforted by their affection and honored by the community—members of which are proud of his distinguished career.

We welcome you for many reasons. We are talking much of celebrating the hundred years of peace between the two great English-speaking races, and every meeting such as this, which brings us face to face, renders that peace more assured. Beneath the superficial differences that divide men there is the broad fundamental fact of human needs and human suffering, and the common grounds of agreement between us all are far more spacious than those of disagreement.

Your profession is one essentially linked to science, in the larger sense of that word, and science knows no international boundary, nor indeed any boundary. More than other men, and more quickly, you learn the inevitable lesson of life—that a man cannot cheat Nature, or find easy or profitable ways by which to evade her universal and eternal laws—and it is natural that in your ranks we should look for and should find the stamp, not only of genius, but of patience, self-reliance, and seasoned judgment—qualities with which the human market is never glutted.

Men still talk of the world not improving. We are still running across our pessimistic friend, the *laudator temporis acti,* but the life work of the modern engineer is a final and efficient answer. By your labors, distance has been annihilated, a thousand needs of men are ministered to as never in the past, and a closer knowledge of other races has made for the extension of human sympathy and the establishment of common and higher standards and ideals.

It is absolutely true that your work, in the last analysis, not only

stands for physical and material development, but constitutes a powerful factor in the shaping of those moral forces by whose agencies life for all people is made more sane, more sweet, and more honorable.

Gentlemen, I again give you the heartiest welcome to the Capital City of this Dominion. I trust sincerely that your visit may carry with it, not only some profit, but much pleasantness, and that you will return to your own country with a strengthened feeling of friendliness to the people who, in the great country north of the International line, are working out their own national problems in a spirit of fortitude and hope, not less fine than that which has characterized your own country.

His Worship, Mayor Ellis.—I have the greatest possible honor, on behalf of the City Council of the City of Ottawa and the citizens of Ottawa, in welcoming the American Society of Civil Engineers to this city. I understand that there are included in your membership a number of Canadian engineers. They, of course, are welcome, too; but we more especially welcome those from the other side of the line, because, as Mr. Burrell has said, there is nothing that conduces more to international friendship and good fellowship and a thorough acquaintance between the citizens of two nations than these comparatively small gatherings of societies such as yours. I am not an engineer. I am, I think, one of the few people in Ottawa who are not engineers. I do not want to refer to local matters particularly, but I wish to warn you, especially those of you who are water-works or municipal engineers, that for three or four years we have been very busy trying to settle what should be a very simple matter, that is the securing of a good and sufficient supply of water; but we have not been able to do so, and I think one of the reasons for our failure is because every second man, or perhaps two out of every three men, are quite convinced that they know more about water than all the engineers who ever existed. If you meet some of these gentlemen, all I can say is that you need not pay very much attention to what they say. We will try to settle all our differences and difficulties in due course, but in the meantime you will undoubtedly find that the city is perfectly full of engineering experts, and especially of water experts. The same condition may arise in other cities where there have been little difficulties to settle, and I feel it necessary to warn you that that condition exists in Ottawa. As I said, I am not an expert in the matter myself, and I generally take the advice of people who are.

One thing about Ottawa, that may perhaps interest you, is that it is a city in the making, just as Canada is a nation in the making. We are a city of perhaps one hundred thousand. Like most other cities that have grown so far, we have not looked far enough ahead, especially in our engineering, and now, thanks to the Dominion Government, we have under consideration a proposition which I think will

Addresses of Welcome (continued).

do a great deal to make the city what it should be, especially from an engineering point of view. With regard to engineering matters, we have been practically for years doing over again the engineering work which we did some years before, quite unnecessarily, I think. Perhaps that is a fault common to all growing cities. However, we hope to remedy this difficulty in this way: The Dominion Government proposes that a Commission be appointed, composed of experts, who will lay down a general plan for the city for perhaps the next one hundred years. That plan will cover the laying out of all parks and grounds, the location of buildings, the entrance of railroads, and the location of railroad facilities, and practically all engineering work. I am strongly in favor of that proposal, because, it seems to me, that is the method on which, not only Ottawa, but every growing city should be managed. There has not been sufficient attention paid to the engineering work, that is, with regard to its permanent character and having it meet the requirements of future generations. We in Ottawa have been satisfied to get along from year to year without making the provision we should for the future; I hope that we have now come to an end of that condition, and that we will be able to have a city planned on a larger scale, and that that plan will be carried out. The Dominion Government has taken an interest in this matter, because this is the Capital of the Dominion, and I suppose they feel that they have some kind of a partnership in the city.

We are very glad to have you come to Ottawa. You will find that something has been done to improve the city and to make it what it should be, and especially what the capital of a country should be. We have still a great deal to do in that direction, but I think you will find that, in the laying out of the city, in what has been done in connection with the embellishment and beautifying of it, we have made some progress, and, at all events, if we have not done what we should, we have given some promise of improvement in the future. I hope that, in view of what has been done by the Dominion Government and the local engineers, you will find your stay in the city a most pleasant and enjoyable one. I know that in gatherings of this kind there is a certain amount of business to be done. All I can urge on you to-day is that you should not tie yourselves down too strictly to business, but should leave yourselves sufficient time to see the city and to take part in the entertainment which will be provided for you. There is one thing that we desire, and that is that in everything the delegates should go away thoroughly satisfied with the city and feeling that they have not only gone through their business programme, but that their visit has been a pleasant and enjoyable one. I have very great pleasure, indeed, in welcoming you to the city, and I hope that when you go away you will go with the most pleasant recollections of Ottawa and of the people whom you may meet here. Perhaps, then,

at some future date, when again you decide to meet outside of the United States, you will decide to return to Ottawa. I can assure you that, whatever we have done for your entertainment this time, we will try to do better next time.

Reply to Addresses of Welcome.

GEORGE F. SWAIN, PRESIDENT, AM. SOC. C. E.—On behalf of the American Society of Civil Engineers, whose spokesman for the moment I happen to be, I have great pleasure in thanking you for your very cordial welcome to Canada and to Ottawa. A meeting of a society like this in a place which is not the home of the majority of its members is a very significant and interesting event. You have well referred to the fact that in science there are no international boundaries, that engineers and applied scientists belong to no nation, that in science there is no American, Canadian, Frenchman, German, Englishman, or Japanese; all are brothers in one great profession. In engineering, I think there is every reason to break down or eradicate geographical and racial distinction, because the engineer, whose work consists mainly or largely in furnishing facilities for transportation that commerce may be carried on between the countries of the world, furnishes also every necessity, comfort, and convenience, which all the world can use and thus tends to make all the world kin. Therefore, we are all brothers here in one great profession. We have visited your fair land before, we know how hospitable you are, and we perhaps have a little fear that you may think we come a little too often. I think we have been here three or four times, but you are responsible for that, you have made us so much at home that we are always glad to visit you. I can only assure you, on behalf of the Society, that we appreciate sincerely all you have done in the past, and what you are doing now; and when it is our opportunity to show in any practical form that appreciation, we shall try to do it in a way that will make you realize the depth of our feeling and the fact that in engineering and the applied sciences we are all one brotherhood.

Adjourned.

SECOND SESSION

June 18th, 1913, 10 A. M.—The meeting was called to order; President George F. Swain in the chair; Chas. Warren Hunt, Secretary; and present, also, about 150 members and guests.

The Secretary announced the programme for the day, and stated that the first order of business was the Annual Address of the President.

The President delivered the Annual Address.*

THIRD SESSION. BUSINESS MEETING.

Business Meeting Called to Order.

The Business Meeting of the Annual Convention was then called to order by the President.

* See page 1237 of Papers and Discussions.

Time and Place for Convention of 1914.

The Secretary presented the following Report of the Suggestions received as to the Time and Place for holding the Annual Convention of 1914:

"I beg leave to report a canvass of the suggestions received from members of the Society as to the Time and Place for holding the Annual Convention of 1914, as follows:

Chicago, Ill.	43	Detroit, Mich.	11
Boston, Mass.	32	St. Louis, Mo.	11
New York City	22	Washington, D. C.	11
New Orleans, La.	17	Salt Lake City, Utah	10
Havana, Cuba	16	San Francisco, Cal.	10
Saratoga, N. Y.	16	Panama, Panama	9
Denver, Colo.	14	Buffalo, N. Y.	8
Kansas City, Mo.	14	Atlanta, Ga.	6
Los Angeles, Cal.	14	Philadelphia, Pa.	6
Pittsburgh, Pa.	13	St. Paul, Minn.	6
Atlantic City, N. J.	12	Duluth, Minn.	5
Baltimore, Md.	12	Nashville, Tenn.	5
Cleveland, Ohio	12		

"The following have received 4 votes each: Birmingham, Ala., Keokuk, Iowa, Minneapolis, Minn.

"The following have received 3 votes each: Asheville, N. C., Honolulu, T. H., Memphis, Tenn., Portland, Ore., Richmond, Va.

"The following have received 2 votes each: Cincinnati, Ohio, Galveston, Tex., Louisville, Ky., Milwaukee, Wis., Niagara Falls, N. Y., Norfolk, Va., Omaha, Nebr., Palm Beach, Fla., Portland, Me., Quebec, Canada, Rochester, N. Y., San Antonio, Tex., Sault Ste. Marie, Mich., Spokane, Wash., Chicago, Ill., or Milwaukee, Wis., Kansas City, Mo., or St. Louis, Mo.

"The following have each received 1 vote: Alaska, Billings, Mont., Bretton Woods, N. H., Cape Cod, Mass., City of Ancon, Canal Zone, Des Moines, Iowa, England, Indianapolis, Ind., Knoxville, Tenn., Lake George, N. Y., London, England, Louisville, Ky., Manila, P. I., Nantucket, Mass., New Haven, Conn., Newport, R. I., Oakland, Cal., Oklahoma City, Okla., Old Point, Va., St. Augustine, Fla., Samoset Hotel, Rockland, Me., San Diego, Cal., Spring Lake, N. J., Toledo, Ohio, Vancouver, Canada, Virginia Hot Springs, Watch Hill, R. I., White Mountains, Buffalo and trip to Soo, Buffalo to Duluth on steamer, Cincinnati or some central city, Duluth, Minn., or Chicago, Ill., Niagara Falls, N. Y., or Buffalo, Panama or Keokuk, Iowa, Pittsburgh, Pa., Philadelphia, Pa., or Cleveland, Ohio, San Francisco, Cal., or Denver, Colo., Saratoga or vicinity, Utica, N. Y., or some other city in central New York State, Somewhere in the South, A Southern City, Some point in the South, A Southern Point, Some place in Texas or the great Southwest, Any suitable place East of the Mississippi River, Any Summer Resort, The Central West.

"The total number of suggestions received is 440.

"As to the time for holding the Convention, the following 384 suggestions have been received:

February	2	August	7
March	8	September	13
April	15	October	11
May	35	November	2
June	217	December	3
July	32		

January, February or March	1	Summer	2
Between January and April	1	Late summer	1
February 22d or July 4th	1	Fall	1
February or March	1	During National Railway Appliance Association Show	1
April or May	2	(This time is suggested in connection with Chicago as the place.)	
May or June	2		
May 27-30 or July 1-4	1		
Last of May or first of June	1		
Previous to June 1st	1	Carnival Week	1
June or July	9	(This time is suggested in connection with New Orleans as the place.)	
June or September	1		
July or August	2		
October-November	1	The opening of the Canal	1
Winter	1	(This time is suggested in connection with Panama as the place.)	
Winter or Spring	1		
Spring	2		
Spring or Fall	2	Any old time	1
Early summer	1		

"The Secretary also has invitations from the Buffalo Convention Bureau, and from the Mayor and Chamber of Commerce of Buffalo, N. Y., and also from the Conventions Bureau of St. Louis, and from the Governor of the State of Missouri, The Mayor of the City of St. Louis, The Merchants Exchange of St. Louis, The Associated Retailers of St. Louis, The St. Louis Manufacturers and Exporters Association, and The St. Louis Sales Managers Association, inviting the Society to hold their next Annual Convention in their cities.

"Respectfully,

"CHAS. WARREN HUNT,

"Secretary."

Invitation to hold Convention in Havana.

THE SECRETARY.—I also have a letter from C. C. FitzGerald, M. Am. Soc. C. E., Secretary of the members of the American Society of Civil Engineers resident in the Island of Cuba, inviting the Society to hold its next Annual Convention in Havana, Cuba.*

"HAVANA, CUBA,

"June 10th, 1913.

"TO THE MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS IN CONVENTION ASSEMBLED, OTTAWA, CANADA:

"The members of the American Society of Civil Engineers resident in the Island of Cuba cordially invite you to hold the Annual Convention for the year 1914 in the city of Havana, Republic of Cuba.

* By instruction of the Meeting, this communication was not read, but is here printed for the information of the membership.

Invitation to hold Convention in Havana (continued).

"We can assure you of an interesting and profitable trip and one that no one will regret.

"The only objection that can be offered to holding it in Havana is probably the temperature, but the thermometer in June is not over 80 degrees Fahrenheit, as the Trade Winds blow from the sea all day, and the land breeze known as the 'Terral' blows at night. The journey can be made by rail from New York in 55 hours, giving a view of the 'Over Sea Railway.'

"In Havana the following engineering works are going on:

"An entire new Sewerage System and Paving costing some $20 000 000, with a tunnel under the harbor and another under the hill on which is the famous Cabaña Fortress, the best example of this type of fortification in the world, and which cost $14 000 000 when labor was cheap and no unions existed and stone was quarried from its own moat. The outfall of the Sewerage System is to the east of the Harbor, laid out into deep water on an exposed rocky coast.

"The modern Pumping Stations connected with this new Sewerage System will be of great interest.

"The dredging of Havana Harbor with clam-shell and dipper dredges, the material from which is sent to sea, and a large modern 20-in. Suction Dredge used in reclaiming several million square meters of swamp land.

"Two wrecking derricks at work removing some two hundred wrecks of all kinds.

"The erection of some 10 kilometers of concrete sea wall with reinforced concrete piles.

"This work will cost upward of $11 000 000.

"There is also in construction an Ocean Freight Terminal combined with storage warehouse and cold storage facilities, consisting of two piers, 700 ft. by 150 ft., double-decked, and a storage warehouse, 800 ft. by 75 ft., four stories high, all fire-proof concrete construction supported on reinforced concrete piles from 45 to 85 ft. in length.

"There are the new freight and passenger terminals of the United Railways of Havana with four large piers of reinforced concrete deck, three on screw piles and one on creosoted piles, and all with steel superstructures.

"The new modern passenger station, handling steam and electric trains and Edison storage battery cars.

"There are two modern coaling plants for ships, built of reinforced concrete and with the latest machinery.

"In connection with these large harbor works are two modern plants for the manufacture of concrete piles.

"There is in construction a new electric power plant and remodeling of the gas plant to cost $2 000 000.

"There are large modern machine and car shops of the United Railways of Havana.

"There is a modern cement factory turning out 800 bbl. of cement per day.

"There are several large factories making cement floor tile of as complicated a design as those made anywhere in the world.

"A trip to the Vento Water-works will be appreciated both from

an engineering and artistic standpoint. This impounds in a space of less than 80 ft. square a spring that supplies the city of Havana and the towns of Marianao, Regla, and Guanabacoa, of more than 350 000 inhabitants, and would supply twice that many if the water were metered to the consumer.

"The water is carried under the Almendares River in an inverted syphon inside a tunnel. The access to the tunnel at either end is by a shaft and a stairway carried on a series of flying arches, and everything is built to a nicety seldom found in this class of work.

"From the tunnel under the river the water continues in a masonry conduit to the city, a distance of about 6 kilometers, where it is deposited in two reservoirs with the necessary valves, etc., for distribution to the city.

"This work was built by the Spanish Military Engineer, Col. Francisco de Albear, to whom a statue has been erected in the Plaza Albear, being one of the few statues ever erected to an engineer.

"Another engineering work of interest is the reinforced concrete arch bridge across the Almendares River, consisting of three spans of 102 ft. and one of 190 ft. This work is described in Vol. LXXIV of the *Transactions*.

"There is also under construction the new Presidential Palace to cost upward of $1 000 000.

"The continuation of the present sea wall and drive will be under construction, consisting of 5 kilometers of concrete sea wall and broad drive.

"The present sea wall has withstood four cyclones and many heavy storms, and is of interest as showing the resistance to disintegration of cement exposed to sea water where there is no freezing.

"There are several sugar mills near Havana that are also of interest, and a trip of two hours on an electric train takes one to the tobacco plantations and pine apple groves of Pinar del Rio.

"As for amusements, we are offered the freedom of the new Country Club that has a fine 18-hole golf course, and which with the grounds and building represent an investment of $180 000.

"We also have the freedom of the Yacht Club and the delightful sea bathing.

"Then there is a trip to Morro Castle and Cabaña Fortress.

"A trip to Matanzas with its beautiful caves and the Valley of the Yumurí River.

"Shark fishing can be enjoyed just outside the Harbor by those who wish to get the man-eater in his native lair.

"For those who desire to make a trip through the Island we will arrange a special train, if a considerable number go, or a special sleeper attached to the regular train that will take them in 24 hours through the center of the Island to Santiago, where they can visit the battlefields of El Caney and San Juan Hill, and, if desired, continue on to Jamaica and the Panama Canal by the Hamburgh-American Line that has a fleet of fine vessels in this trade.

"Those who would see the Island and want to make a quick return to New York could go to Nipe Bay, where they could get connection with the Royal Mail Steamer to New York. At Nipe Bay is the Preston Sugar Mill, one of the largest and most modern of Cuba.

Invitation to hold Convention in Havana (continued).

"At the Felton mines the Spanish-American Iron Co. have a surface deposit of ore mined by drag scraper and handled down a steep incline standard gauge railway to the drying and concentrating kilns, and thence loaded by a modern plant on to the ships which convey it to the United States. At Preston there is a good hotel with moderate rates.

"As for Havana, it is a city of 300 000 people, consisting of the old, or what was the walled city, and the part that lies outside the walls and extending now to the suburbs with beautiful villas of classic architecture that is nearly always pleasing.

"Havana has some of the largest and finest equipped hospitals, and some of the largest club buildings in the world.

"There are two clubs with 30 000 members each and with buildings that cost $500 000 and $1 000 000, respectively. The latter under construction.

"There are plenty of good hotels and with very low rates in the summer.

"While the streets are naturally torn up on account of the Sewering and Paving, the city is clean, and one can get a real object lesson in Modern Sanitation which turned one of the dirtiest and most unhealthy cities in the world into one of the cleanest and healthiest in the world, where there has not been a case of yellow fever in six years, and where only two cases of Bubonic plague developed when it was imported from the Canary Islands, whereas in Porto Rico it grew to alarming proportions.

"It is a city where still lives the man who first advanced the mosquito theory of yellow-fever transmission and in this way made the Panama Canal possible.

"In Havana, those engineers who are connected with industrial plants can learn the needs of export business as regards packing, shipping, documents, and all that pertains thereto, and why the United States is so far behind its competitors in these matters, which we must learn if we are to receive the benefit of the Panama Canal and the trade it should bring us with South America.

"From Cuba, one of the late-born republics, one started by the United States, we can well learn something. The Secretary of Public Works is a member of the President's Cabinet, and the portfolio is now held by Sr. José R. Villalón, Assoc. Member of the American Society of Civil Engineers, and President of the Society we have formed to endeavor to obtain the 1914 Convention, which warrants you that all possible will be done by the officials to make your visit enjoyable.

"The President of the Republic is a Civil Engineer, a graduate of Cornell, and put in his early days on the Nicaragua Canal Survey, and in the war for Cuban independence rose to be a Major General and has since then managed three of the largest sugar estates in the Island.

"Here the engineering profession is looked up to and honored more than in the North, and at this time, when so much thought is being given to bettering the engineering profession, some good lessons can be learned.

"Pardon this long invitation, but, though we are at the doors of the

United States, many think we are as far away as the Philippines, and we must make our case known.

"We have sufficient funds pledged to make all short trips free to those who come.

"Come down and you will find your visit most pleasant and profitable, and we can assure you of a fine time.

"For the Committee,

"C. C. FitzGerald, M. Am. Soc. C. E.,

"Secretary."

The President.—The customary procedure is to refer this matter to the Board of Direction with power to act.

It was moved, seconded and carried, that the selection of the time and place for holding the 1914 Annual Convention be referred to the Board of Direction with power.

The Secretary.—I have a report of the Board of Direction to the Society.

"REPORT OF BOARD OF DIRECTION UPON 'IMPROVEMENT IN THE METHODS OF THE PRESENTATION OF PAPERS.'

Report on Improvement in Method of Presentation of Papers.

"In accord with the motion passed at the Annual Meeting of the Society, 'That a Committee of five be appointed to consider an improvement in the methods of the presentation of papers before this Society,' the Board of Direction has given careful consideration to the matter referred to it.

"A detailed statement has been prepared relating to the presentation of papers and the discussion had at the ordinary meetings of the Society for the six-year period from 1907 to 1912, inclusive, which was published in the February Number of *Proceedings*, page 103, for the information of members.

"The Board has inquired into the current practice of other Societies, invited individual suggestions, and now makes the following recommendations, largely in accord with past practice, but embodying some new features, and outlining a course of procedure for the convenience of authors and of the Publication Committee:

"1.—That every author be required to submit with his paper a summary giving the objects of the paper, a brief digest of its contents, and a concise statement of its conclusions, to be read at the meeting so that members who have not been able to read the paper in advance of the meeting may be able to follow and take part in the discussion of it.

"2.—That the author of each paper approved for discussion be urged to present his paper in person, or to give at least thirty days' notice to the Secretary that he will not be able to do so, and to suggest the name of some member to present it for him who is especially fitted to do so. That in default of such suggestion by the author, the Secretary either find some such substitute, or present the paper himself.

"3.—That the author be requested to submit with his paper a list of members of the Society especially qualified to discuss his paper, and that the Secretary call the paper particularly to the attention of these

Report on Improvement in Method of Presentation of Papers (continued).

members and others locally known to him as likely to be interested in it, urging them to be present at the meeting at which the paper is to be presented and to join in its oral discussion.

"4.—That the Secretary, in calling the attention of local members to the paper, give, so far as practicable, the names of men who have promised to discuss the paper upon the evening of its presentation.

"5.—That subjects of similar nature be grouped, for discussion at the same meeting, when possible.

"6.—That papers lending themselves to oral discussion be given preference for presentation at the semi-monthly meetings, and that papers better suited to written discussion be printed in *Proceedings*, without oral discussion so far as practicable.

"7.—That oral discussion be encouraged in every way possible.

"8.—That the printing of his discussion be optional with the speaker.

"9.—That the use of lantern slides for illustrating papers and discussions be encouraged, and that, when considered advisable by the Publication Committee, the Society have slides made, at its expense, from photographs or plans furnished by the author."

THE PRESIDENT.—This report does not call for any action on the part of the Society, unless the Society requires it.

THE SECRETARY.—The following amendment to Article VII of the Constitution has been received. It has been mailed to all members; it reads as follows:

Proposed Amendments to the Constitution.

"Amend Article VII—Nomination and Election of Officers—as follows:

"Strike out Section 1, and substitute the following:

"'The Board of Direction shall, from time to time, divide the territory occupied by the membership into thirteen geographical districts, to be designated by numbers. District No. 1 shall be the territory within fifty miles of the Post Office in the City of New York. Each of the other districts shall be, as nearly as practicable, contiguous territory, and shall be designated as Districts Nos. 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, and 13. The Board shall announce such division to the Society on or before the first day of March in each year.'

"Strike out the first paragraph of Section 2, and substitute the following:

"'At the Annual Meeting of each year, seven Corporate Members, not officers of the Society, shall be appointed by the meeting to serve for two years. They shall be selected so as to provide, with the seven members holding over, two members from District No. 1, and one from each of the remaining twelve Districts; and these, with the five living last Past-Presidents of the Society, shall be a committee to nominate officers for the Society.'

"Strike out the word 'and' in the fifteenth line of the third paragraph of Section 2, and after the figure '7' add: ', 8, 9, 10, 11, 12, and 13.'"

THE PRESIDENT.—This matter, under the Constitution, comes necessarily before the meeting, and then the amendment shall be voted upon as amended, and if not, it shall go to ballot as it is.

Discussion on Proposed Amendments to the Constitution.

FREDERIC H. FAY, M. AM. SOC. C. E.—There being two amendments proposed on this subject, I move that these two amendments to Article VII be considered together.

THE PRESIDENT.—You have heard the motion; what is your pleasure?

WALTER H. GAHAGAN, M. AM. SOC. C. E.—I move that the amendments to the Constitution be taken up separately.

THE PRESIDENT.—Mr. Fay's motion is that the amendments to Article VII be considered together.

J. A. OCKERSON, PAST-PRESIDENT, AM. SOC. C. E.—If so, they would have to be voted on together. I think each amendment ought to be considered by itself on its own merits. One deals with the arrangement of districts which is entirely independent from the Nominating Committee, and they should be voted upon independently.

THE PRESIDENT.—What is your pleasure with the motion that the amendments be considered independently?

The ayes and noes were called for and the question was declared carried.

A MEMBER.—I would like the Secretary to explain about the arrangement of districts.

THE SECRETARY.—As a member of the Committee of the Board which studied this matter I can perhaps explain the effect of this amendment. At present we have seven Geographical Districts, the Resident District, and six others. The difficulty heretofore, and at present, is that the outlying districts are geographically too large. The representatives from those districts do not represent any special community in some cases, and the idea of adding six more districts is that while the number of members of the Nominating Committee, and of the Board of Direction, would be exactly the same, each of those members will represent more nearly a constituency. That, in brief, is the idea. It is in order to get as nearly as possible the same number of members in each of the several districts. In the present arrangement we have, for instance, Virginia and Texas in the same District; the States of Washington and Colorado in the same District; and the New England States in the same District as all of Canada, Europe, and Africa. It is thought that by having six more districts the membership of the Society will be able to have a more direct representation on the Board and on the Nominating Committee.

THE PRESIDENT.—This vote is not on the amendment, but simply as to whether it shall be amended before it is sent out to the Society for ballot.

A MEMBER.—Do I understand that that simply applies to Section 1, or to the whole thing?

Discussion on Amendments (continued).

THE PRESIDENT.—To Section 1.

THE SECRETARY.—But the vote is on the whole thing?

THE PRESIDENT.—Yes, the amendment which is on this sheet, entitled "An Amendment to Article VII," contains this section. Now, do you wish these to be considered section by section?

A MEMBER.—Was not that motion carried?

THE PRESIDENT.—I did not so understand it.

THE SECRETARY.—The first of these sections simply divides the territory occupied by the Society into 13 instead of 7 Districts, and the other provides how the Nominating Committee shall be appointed from those districts.

THE PRESIDENT.—The motion has reference to Section 1 of Article VII. Those in favor of passing Section 1 of Article VII——

THE SECRETARY.—Pardon me, Mr. President, I do not think that is necessary. The Constitution says it shall be sent to ballot unless amended in a manner pertinent to the original amendment.

THE PRESIDENT.—Then, shall it pass?

D. C. HUMPHREYS, M. AM. SOC. C. E.—It would certainly help me very much if some member would express his approval of the motion or of the amendment as proposed. I think it would be a valuable guide to men living at a distance. A man living at a distance may read that the section was approved, and it is likely if he is pleased with it, that he will vote for it. Now, I move that we get an expression of the views of the Society on it.

THE PRESIDENT.—Mr. Humphreys moves that the meeting express its approval of the amendment to Section 1.

J. A. BENSEL, PAST-PRESIDENT, AM. SOC. C. E.—I think an action of this kind, with the small number present, would be distinctly opposed to what is contained in the Constitution, which is that these matters should receive approval or disapproval on letter-ballot. It should not go out as an amendment to the Constitution with the approval or disapproval of this meeting. I therefore move in amendment that this meeting do not pass officially on any of the amendments to the Constitution as proposed.

GARDNER S. WILLIAMS, M. AM. SOC. C. E.—I beg to take issue with the view of the last speaker. The Constitution provides that we can act on them at this meeting and send them to the Society to be voted upon. Surely, if we can vote in favor of the amendments, or vote to make an amendment, we have the right to say whether we are satisfied with one when it is proposed. I think the membership will be better qualified to discuss them right here, if the Society has the right to discuss them, and set its approval on them in this form. It seems to me that the last speaker is mistaken, and I would endorse the motion already put.

MR. OCKERSON.—It has got to go to ballot unless amended.

Frank W. Skinner, M. Am. Soc. C. E.—I do not think it is a question of approval or disapproval. It might not be right to do that, but I think Mr. Williams is right when he says that we have the privilege of amending the amendment, and that this body has the right to approve of any amendment, as this is the fountain-head of information for the body. I think it is certain that those amendments are entirely proper, and there exists here the probable information to acquaint us with the probable effect and operation of those amendments, and what their value will be, and I think it would be a good thing and would clear the atmosphere, and help those here, as well as those removed from us, to discuss the matter.

Henry B. Seaman, M. Am. Soc. C. E.—It seems to me there should be provision for obtaining the views of all the members of the Society, rather than merely those who are here, and thus get both sides of the question. I feel that we are here to revise the Constitution, if it is needed, and if not, we can pass on these resolutions with our approval, so far as this meeting goes.

T. Kennard Thomson, M. Am. Soc. C. E.—There has been no apparent objection to the amendments, and I therefore move that the discussion close.

The President.—It seems proper that this meeting should take some line of action expressing its approval of the amendments.

H. J. Burt, M. Am. Soc. C. E.—I would like to hear from some one who has given consideration to this amendment, and to hear in full the reasons for its introduction.

The President.—The motion is that this meeting express its approval of Section 1 of Article VII.

The motion was put and declared carried.

The President.—Now, as to Section 2—does anybody wish to amend the amendment to Section 2?

Mr. Fay.—There are two amendments to Section 2, both of which are different, and I think they should be considered together. The first was read by the Secretary, but the second has not been read, and I move that we consider them both together. They have to do with either the election or the appointment of the Nominating Committee.

A Member.—I second that.

Mr. Gahagan.—There is something I would like to understand. These amendments are referred to us, and I would like to hear them read. Is it that we shall have a larger number of units in the membership? I do not understand whether or not that is part of Section 2.

The Secretary read the following proposed amendment:

Second Proposed Amendment to the Constitution.

"Amend Article VII as follows:

"*Article VII, Section 2.*—Strike out Paragraphs 1 and 2 of Section 2 of Article VII and substitute therefor the following section:

Second Proposed Amendment to the Constitution (continued).

"'2.—Seven Corporate Members, not officers of the Society, one from each of the geographical districts, shall be elected annually in the manner herein prescribed to serve for two years; these members with the seven members holding over and the five living latest Past-Presidents of the Society to constitute the Nominating Committee to nominate officers for the Society. The manner of election shall be as follows: Before the fifteenth day of September there shall be mailed to each Corporate Member, whose address is known, a notice, with form and envelope for voting, requesting him to suggest the name of one Corporate Member (not an officer of the Society) from his district as a candidate for nomination for member of the Nominating Committee; these suggestions to be made to the Board of Direction by a preliminary letter ballot to be received by the Board at a meeting to be held about the first of November, and opened at said meeting and counted under the direction of the Board. The polls shall be closed at noon on the day of said meeting and the time of closing the polls shall be stated in said notice. Before the first day of December there shall be mailed to every Corporate Member whose address is known a second notice, with form and envelope for voting, said notice to state the time of closing the polls on the final ballot and to contain, as nominees for the Nominating Committee from each district, the names and residences of the two persons receiving the highest number of votes in such district, in the order of their standing as the result of the preliminary ballot. In case two or more persons receive the same vote for first or second place on the preliminary ballot the names of all such persons shall appear on the second notice. Each voter may vote only for one member of the Nominating Committee from his district. On the final ballot the polls shall close at noon on the day preceding the Annual Meeting and the ballots shall be canvassed under the direction of the Board of Direction. The seven members receiving the highest votes in their respective districts on the final ballot shall be declared elected members of the Nominating Committee. Announcement of elections by this ballot shall be made at the Annual Meeting. In case of a tie vote in any district, the Annual Meeting shall elect the member of the Nominating Committee from among the persons so tied. Vacancies in the Nominating Committee may be filled by the Board of Direction.'

"Paragraphs 3 and 4 of Section 2 of Article VII shall constitute a new section numbered 3, and for the words 'This committee' in the first line of Paragraph 3 substitute the words 'The Nominating Committee.'

"Sections 3, 4, 5, 6, and 7 of Article VII shall be renumbered Sections 4, 5, 6, 7, and 8, respectively.

"In the second sentence of present Section 5 (new Section 6) of Article VII, insert after the word 'nominated' the words 'for Officers of the Society,' so the said sentence shall read:

"'This ballot shall include the names and residences of all persons nominated for Officers of the Society in accordance with this Article, their grades of membership, and, in case of nominees for Directors, the number of the district in which they reside.'"

Discussion on Proposed Amendments to the Constitution.

Mr. Williams.—I would like to call attention to the fact that if this amendment be adopted as at present, and we also adopt an amendment to the Constitution changing the number of districts, there will be an incongruity in the language of this amendment, with the language of the Constitution whereby there be seven districts. I move that in this amendment be struck out the word "Seven" and inserted the word "One," and changing the word "Members" to "Member," the word "officers" to "an officer," so that the Article will read: "One Corporate Member, not an officer of the Society, from each of the geographical districts shall be elected annually," and then, no matter how many districts there are, we will have one representative.

Mr. Fay.—I would like to call attention to the fact that if Mr. Williams' amendment is carried it will double the number of representatives on the Nominating Committee. If one is elected from each district for a period of two years, instead of having 14 we should have 28, and I would offer as an amendment to the amendment already proposed, and also for the election of the Nominating Committee.

[Mr. Fay handed to the Secretary a typewritten sheet, containing Section 1 of the proposed amendment relating to increase in the number of Districts, coupled with his proposed amendment in relation to the method of electing the Nominating Committee. This was not read.]

Mr. Williams.—Is it the intention to have the members of the Nominating Committee elected for two years?

The Secretary.—In this amendment proposed by Mr. Fay, it is proposed to make the last amendment conform to the thirteen districts instead of the seven. It is very clear that that is all it does.

The President.—Does the Society wish to have it read? The amendment which was proposed by this meeting a few minutes ago, if carried by this Society, will divide it into more than the present number of Districts. The amendment which the Secretary read first did not contemplate any division into a greater number of Districts, but that amendment has been amended so as to take into account the greater number of districts provided if the previous amendment is carried.

Mr. Williams.—Then, as this appears to cover the point, I withdraw.

The Secretary.—I would like to move another amendment to that proposed by Mr. Fay, to the effect that the word "last" be changed to the word "latest," this being the word used in another part of the Constitution.

Chas. F. Loweth, M. Am. Soc. C. E.—I would like to know if this would restrict our vote to but one member of the Nominating Committee. As I understand it, we would be limited by ballot to vote for but one member of the Nominating Committee.

Mr. Fay.—The procedure for the election is to be substantially

Discussion on Proposed Amendments (continued).

the same as now—that is, suggestions are sent in and a ballot is sent out on which at the present time we vote for one member of the Nominating Committee from our district. That is to be followed in the future, only instead of having the ballot ratified at your meetings, it provides for the definite election of the Nominating Committee.

Mr. Loweth.—We ought to make it possible to have the members of the Society vote for a larger number than one member. I am interested in this question, not only as the representative of my district, but other districts, and it seems wrong to vote for only one member of this Nominating Committee.

Mr. Ockerson.—Does this cover all the amendments to Article VII?

The Secretary.—This completes the amendments.

Mr. Ockerson.—There is one that the members have already passed on?

The President.—That is Section 1.

Mr. Ockerson.—Is that included in this?

The Secretary.—Yes.

Mr. Williams.—As a question of the English language, I do not think it is proper to say "The five last or latest," as there can be only one of each, but it should be the "last five or the latest five," and I would move that the language be changed to the following: "the latest five presidents, etc." (Laughter.)

The Secretary.—I am sorry I spoke. (Laughter.)

The President.—Now, the amendment before us is the amendment to Section 2 of Article VII.

Onward Bates, Past-President, Am. Soc. C. E.—It seems to me that this Society should have the final vote on those members of the Nominating Committee. It does not seem to me that the vote of the District should be final, and I should think we ought to have the final word. It strikes me that it would be necessary to retain that right. I would like to hear from Mr. Fay on that—I think he originated that idea.

Mr. Fay.—I am asked a question, but I do not know whether I can answer it, for we are getting this matter so badly confused among ourselves. I think it would be bearing on the discussion to call attention to the fact that we scarcely know where we art at, or what we are doing. We have two different amendments, either one of which will kill the other. It is very unfortunate to have to amend either of these amendments, so they would go out to the members to be voted upon in such a shape that they could not amend it. There might be something they would like to amend if they had the opportunity, but in the way they are mixed up now, it is hard to answer yes or no to this question. Is it to the effect that our Annual Meeting should retain the right to confirm the election of members of the Nominating Committee?

MR. BATES.—That is the opinion I hold.

A MEMBER.—I hold that view, too; and I wish to say that in a large district we have difficulty in electing a Nominating Committee. Very few take part in the election, and in the past we have had members who were chosen just by chance, and if we do not retain the right to confirm the election we are apt to have a very poor membership.

THE PRESIDENT.—The Chair does not understand that there are two matters here in conflict. The amendment to Section 1 has been carried by the Society, and the amendment to Section 2 is up. The question arises as to whether they will be voted on separately. If that were done, I think the difficulty would be obviated.

A MEMBER.—It seems to me that there are two different forms for amending the same Section of the same Article, and we cannot cut out one Section of an Article, and substitute something else, and then make another that changes both.

CHARLES M. DAVIS, ASSOC. M. AM. SOC. C. E.—I am a member from one of the extreme outlying Districts and have never attended a meeting of the Society in our home, and for that reason I keep in poorer touch with the things that happen there than perhaps I should. The Constitution, if amended, must carry some reasons for its amendment, but members unfamiliar with the clauses of these amendments have very little chance to understand the conditions. I would like to ask that this amendment be explained and that the party who proposed it give us his objections to the Constitution as it exists. I believe some persons may see the advisability of putting this into the Constitution, but I do not believe in meddling with our Constitution to any great extent, except where it is absolutely necessary. If it has been satisfactory in the past, why should it not be permitted to continue that way? I believe it is simply a difference between the English Constitution and our own. In our own we have very few amendments. The English Constitution is, of course, the entire law of the land, and if we are to take our own Society's Constitution and incorporate in it all the modes of procedure, then we are violating the principles of the Constitution of our own United States, and I personally see very little use in putting in an amendment or changing the Constitution if it is not necessary.

MR. GAHAGAN.—I am very much in sympathy with the last speaker. We have a Constitution that has been working very well, and a distinct board of officers of the Society, and I am under the impression that this case did not originate with the officers, but perhaps two or three per cent. of the members, or about ninety members out of five thousand.

THE PRESIDENT.—That perhaps does not represent the number in favor of it.

Discussion on Proposed Amendments (continued).

Mr. Gahagan.—That is the idea. I do not understand why it should be put to vote.

Mr. Fay.—The amendment providing for the election of the Nominating Committee is the result of careful consideration on the part of a sufficient number of members from different parts of the country—men who have had close connection with the affairs of the Society, either as members of the Board of Direction, or members of the Nominating Committee. It is not by any means a hasty action, and furthermore, the number of names signed to this amendment does not by any means represent the number of people in favor of it, as I have heard some expressions in favor of it from all parts of the country, and especially at the Seattle Convention last year. At the present time one nominee is nominated for each particular office of the Society. So far as the election of officers is concerned, there is no choice by the Society itself. The full responsibility for the election of the officers of the Society practically rests with the Nominating Committee—they are the ones who actually select the officers for this organization. It is felt that this Nominating Committee is perhaps the most important committee that this Society has, and it should be selected with great care and in the proper form. Within the last few years, as has been suggested by Past-President Bates, the method provided for the nomination and election of the Nominating Committee has been carried out by a preliminary ballot which asks for suggestions of names from each District to serve on the Committee, and then a second ballot is sent out which is also informal, and the returns, when they come in, do not come in the form as provided for in the election of officers, but the ballots come in, and, so far as I know, any employee or any one in the Secretary's office may have access to these ballots. It seems to me that it should be safeguarded the same as the election of officers, that the ballots should come in in proper form, and provision made for the ballots being counted by the Board of Direction, the same as in the case of the election of other officers. The whole idea is to provide for the election of a Nominating Committee, making the matter one of greater importance than at present, because the Nominating Committee is the one which practically elects the officers of this Society.

Mr. Bates.—I would like to differ with the last speaker, for that is not my idea of it, I think this amendment takes away from the Annual Meeting the right of electing members to the Nominating Committee and it is doubtful if that is a good thing to do.

J. Waldo Smith, Vice-President, Am. Soc. C. E.—I am at sea in this matter, and I would like to see these amendments disposed of entirely. I would ask that they be considered separately.

The President.—Section 1 of Article VII has been disposed of, but not the amendment as a whole.

Mr. Smith.—I do not see how they can be considered together—I do not think that was the idea.

The President.—The vote which I put, and which was carried, was that Section 1 of Article VII as read was approved by the Society, and we are now considering Section 2 and the two amendments to it.

M. J. Riggs, M. Am. Soc. C. E.—As I understand the two amendments to Section 2 of Article VII, the one read by the Secretary only makes changes as to the Districts, while the other changes the entire result. Both of those amendments will have to go to vote—the whole membership will have to vote on these two methods of carrying on our business. It is well enough to consider it here, but I can take the choice of the two when it comes to me. Personally, I am in favor of the amendment of Mr. Fay, but that is not for me to decide here.

The President.—I think you are right—we should vote to send out the ballots on each section separately—not that the whole thing should be carried on in its entirety.

A Member.—We agree on Section 1 making more Districts. Now we only disagree on Section 2, and I can have my choice when ready to vote on this matter.

Mr. Ockerson.—Seeing that Mr. Fay has offered an amendment—the one already sent out—if this is the case, I move that Mr. Fay's amendment be adopted so that we will get results one way or the other.

The Secretary.—I may be able to clear this up by saying that a member who is in favor of dividing the Society into thirteen districts instead of seven as we now have, and who is not in favor of Mr. Fay's amendment as to the election of a Nominating Committee, would be unable to express his opinion—he would have to vote against this amendment.

The President.—Mr. Fay's motion is in two parts. If the Society votes separately on those, what difference will it make?

The Secretary.—I do not think it will make any.

A Member.—I think the Chair is quite right in saying that they should be set out separately, because they may be amended by a majority of the meeting. I maintain that the amendment which provides for the election of a Nominating Committee cannot be amended by being divided at this meeting and the first amendment substituted for it. It is not an amendment to the original motion, but, as the President says, that the Society be allowed to take the method it desires, and I consider that fair.

A. N. Talbot, M. Am. Soc. C. E.—I can see some possible results from that which might not be satisfactory. For instance, both of those amendments might be adopted, in which case there would be a question as to the legality of the vote. Again, either one of the two sections

Discussion on Proposed Amendments (continued).

of Section 2 might be adopted, or Section 1 be adopted, in which case the result would hardly be satisfactory. I wonder if it is possible to agree on an amendment to each of these in a way that would be identical, and if necessary to set out the amendments so that they be both the same.

R. S. WESTON, M. AM. SOC. C. E.—Might I ask that the consistent amendments be grouped, and that they be voted upon on the Australian ballot system?

THE SECRETARY.—There does not seem to be any difficulty. You have an amendment to Section 1 of this Article, and an amendment to Section 2, and they could be put together. I think every member would have an idea which he wanted to vote for.

THE PRESIDENT.—The motion has been made that Mr. Fay's amendment be approved by this meeting and sent out to ballot.

A MEMBER.—I wished you to decide whether this body wanted to amend this one or send out the original one.

THE PRESIDENT.—Do you wish to propose any amendment to Mr. Fay's amendment?

A MEMBER.—I move that Mr. Fay's amendment to the original amendment to Article VII, which was circulated on four sheets of paper, be approved by this meeting and sent out to letter-ballot.

MR. BENSEL.—I have just been wondering whether that extreme pessimism which was mentioned in our President's Address can apply to the members who are transacting our business. Here we come to one of the most important things the Society has to deal with, the care of its Constitution. The amendment has been created—the Secretary and President have tried to explain how it applied, and without any reference to that particular brand of intelligence which the rest of the members have at their command, I am bound to confess that I do not understand the application of these principles to the Constitution. It seems to me that this method being pursued, although it may be in line with the Constitution, is one that cannot but lead us into difficulty. Even if, as Mr. Fay has said, the amendment shall be pertinent to the amendment as it was originally, it seems to me that this meeting might send out these amendments as proposed, and send it in either case with the Committee's opinion of these amendments, and with particular reference as to how they would apply to the Constitution as it now is. In that way the general membership of the Society would be advised as to what is intended by the amendments and would not be led into amending the Constitution without the knowledge of how it would apply. (Applause.)

THE PRESIDENT.—The motion is that Mr. Fay's amendment to the original amendment be adopted.

MR. THOMSON.—Would that not conflict with the motion you have already passed in regard to the first section?

The President.—I think not. We have considered Section 1, and we are now considering Section 2 only.

Mr. Loweth.—Would not Mr. Fay change his amendment to make it read in this way, that each voter may vote for but one member of the Nominating Committee from each district, and then in the seventh line from the bottom of this printed list to read: "thirteen members receiving the highest vote to be elected members of the Nominating Committee," omitting the words, "in their respective district." As it stands now each member would have a vote for one-fourteenth of the Nominating Committee.

E. T. Perkins, M. Am. Soc. C. E.—I move that the motion before the house be amended to take effect as Mr. Bensel suggests, and that the motion be sent out from this meeting as suggested by the Secretary.

The President.—I do not think that is as Mr. Bensel suggested.

Mr. Bensel.—It seems to be for the benefit of the Society that they should be sent out in their printed form as at present. The addition of such advice from a Committee appointed at this meeting, explaining in what manner these amendments would apply, would be of value.

The President.—The Constitution provides that any amendment must be sent out to ballot, or referred to a Committee.

Mr. Bensel.—I was just wondering if we could not by having a Committee appointed by the Chair get the information better than by continuing this discussion, as we hardly understand the amendment as proposed.

The President.—They must go out as amended.

Mr. Bensel.—We have them as originally proposed, although, as I say, the amendment to the amendments should go out and the members vote on one or the other.

The Secretary.—Mr. President, it seems to me that if a motion is made that the Secretary be instructed to send out two ballots, one of which shall embody all contained in the first of these amendments, which relates to the changing of the number of Districts from seven to thirteen, and to retain the present method of appointing the Nominating Committee; and also to send out a similar ballot carrying out the idea of Mr. Fay, in electing a Nominating Committee, having regard to the new form of Districting the Society, that this will enable the members to decide as to how they will elect the Nominating Committee, and have thirteen districts or seven; those are the only questions, and it would be easy to instruct the Secretary to send out such ballots and the matter would then be put before the Society.

Allen Hazen, M. Am. Soc. C. E.—It seems to me that the matter has gone beyond this meeting. The Constitution provides a method by which a matter of this kind may be referred to a Committee, and it seems to be eminently fitting that they should be referred to a

Discussion on Proposed Amendments (continued).

Committee for presentation in better shape, and, if in order, I move that the amendment be referred to a Committee.

THE PRESIDENT.—It is moved and seconded that these amendments be referred to a Committee. The Constitution provides that the meeting may refer the matter to a Committee for further information.

MR. OCKERSON.—I was anxious to see Mr. Fay's amendment disposed of in some shape, and I would like to have it done.

A MEMBER.—I think the motion to refer the matter to a Committee takes precedence of all other motions.

THE PRESIDENT.—Yes, that is right.

A MEMBER.—To what kind of a Committee?

THE PRESIDENT.—It is for this meeting to decide how it is to be appointed.

MR. HAZEN.—I think that is a matter that could be left to the President, and I will amend my motion that it be left to a Committee of five to be appointed by the President.

THE PRESIDENT.—It is moved and seconded that the whole matter be left to a Committee of five, to report at the next meeting, as provided for in the Constitution.

The motion was put and carried.

Proposed Amendments to Articles V and VI.

THE SECRETARY.—There is another amendment to the Constitution, which must come before this meeting, it reads as follows:

"Amend Articles V and VI as follows:

"*Article V, Section 1.*—Strike out the first sentence and substitute the following:

" 'The officers of the Society shall be a President, four Vice-Presidents, eighteen Directors, a Secretary, and a Treasurer. These officers, except the Secretary, together with the five latest living Past-Presidents, who continue to be members, shall constitute the Board of Direction in which the government of the Society shall be vested, and who shall be the Trustees as provided for by the laws under which the Society is organized.'

" '*Article V, Section 2.*—First Paragraph. In first sentence strike out ', Secretary', so that the sentence shall read as follows:

" 'The terms of office of the President and Treasurer shall be one year; of the Vice-Presidents, two years; and of the Directors, three years.'

"Second Paragraph. In first line insert after the word 'officer' the words 'elected by the Society' so that the paragraph shall read:

" 'The term of each officer elected by the Society shall begin at the close of the Annual Meeting at which such officer is elected, and shall continue for the period above named or until a successor is duly elected.'

"*Article VI, Section 4.*—Strike out the first two paragraphs of the section and substitute therefor the following:

"'The Secretary shall be a Corporate Member of the Society. He shall be elected annually by the Board of Direction at a meeting to be held not less than twenty days after the Annual Meeting and shall hold the office until his successor is elected, provided that a majority of the whole Board of Direction shall be required to elect the Secretary; this vote to be taken by letter ballot to be canvassed by the Board of Direction at said meeting.'

"'He shall be, under the direction of the President and Board of Direction, the executive officer of the Society. His whole time shall be given to the Society.'

"*Article VI, Section 6.*—In the second line after the word 'by' insert the words 'a majority of' and after the word 'Direction' insert the following: ', this vote to be taken by letter ballot to be canvassed by the Board of Direction'; so that the section shall read as follows:

"'6.—The Secretary and Treasurer shall be paid salaries to be determined by a majority of the Board of Direction, this vote to be taken by letter ballot to be canvassed by the Board of Direction; but such salaries shall not be reduced during the term of office, as provided in this Constitution. All other salaries shall be fixed, from time to time, by the Board of Direction.'"

THE SECRETARY.—I also have a communication from a number of members, Mr. President, which I think must be read. Discussion on Proposed Amendments.

"*To the Business Meeting of the Annual Convention**
American Society of Civil Engineers:

"Under date of April 30th, 1913, several proposed amendments to the Constitution of the Society were sent in regular course to the members. They consist of two groups, one of which changes the status of the Secretary by removing him as a member of the Board of Direction, and adds other details as to the method by which he shall be elected; the other changes and fixes the details of the procedure for electing members of the Nominating Committee, and incorporates these details in the Constitution, taking them out of the hands of the Board of Direction, and the final action away from the Annual Meeting.

"The undersigned believe the adoption of these amendments inimical to the best interests of the Society for the following reasons:

"1. No amendment to the Constitution should be adopted, or even proposed, unless there is some necessity for it.

"2. The first group, if adopted, will lessen the importance of the office of Secretary. If it is intended that the Secretary shall be only a clerk, why should he be required to be a Corporate Member of the Society?

*The Secretary read the communication and the first 64 names signed thereto, and stated that in addition to these signers, all of whom either are or have been Officers of the Society, it is signed by 698 others residing in 23 of the United States as well as in Cuba, Panama, Manitoba, Ontario and Quebec, and that of the total number of signers 762 358 live in the Resident District and 404 are Non-Resident.

Discussion on Proposed Amendments (continued).

"Under the requirements of the Constitution, which the proposed amendment does not change, the Secretary is the Executive Officer of the Society, and, as such, must represent it as other scientific, governmental and secular organizations are represented. He is required also to be a correspondent, a librarian, a house and office manager, an editor, a publisher, an accounting officer, and the every-day representative of the Society. His duties must be performed with care and thoroughness, and he must have executive capacity and good business judgment, as well as literary ability and familiarity with the broad field of Engineering.

"3. As long as these are the requirements of the position it is evident that the Secretary should continue to be a member of the Board of Direction, as he has been since the organization of the Society.

"Prior to 1895 the Secretary was elected by the membership. This method proving unsatisfactory a change was made, and, beginning with that year, the Secretary has been elected by the Board of Direction. The present Secretary was the first elected under this rule, and has since been re-elected annually. This continuity of service has been of great value to the Society as is evidenced by the Annual Reports of the Board during this period. As the Board is entrusted with the management of the affairs of the Society, and is largely dependent on the efficiency of the Secretary, there can be no question but that the present method of election is based on sound business considerations. The approval of the Board of the conduct of the business of the Society at the present time is evidenced by a report of the present Finance Committee published in the April, 1913, number of *Proceedings*.

"The other group of amendments proposes to incorporate in the Constitution a fixed method of election of members of the Nominating Committee.

"1. By the present method, suggestions received from the various Geographical Districts are presented to the Annual Meeting, and that Meeting appoints the Committee. The details of securing these suggestions are in the hands of the Board of Direction. It is now proposed that instead of receiving suggestions, ballots be issued, said ballots to be canvassed by the Board of Direction, and the result reported to the Annual Meeting.

"2. In the past it is believed that the suggestions received have not in many cases reflected the sentiments of a majority of the members in each district, and that under the proposed amendment it may happen that a very few members in a district may thus name a member of the Nominating Committee.

"3. There have also been some indications in recent years of the use of log-rolling methods in the selection of members of this Committee, and the power now reserved to the Society in Annual Meeting may be useful to correct this growing evil.

"4. It is poor policy to put details of this kind into the Constitution, and the present procedure should be considered as under trial, and the Board of Direction should be left free to improve it as need arises.

"We therefore recommend to the membership that these amendments, which, under the Constitution, must be issued for letter-ballot, be defeated.

John F. Wallace	Onward Bates	J. A. Bensel
S. L. F. Deyo	J. Waldo Smith	Geo. H. Pegram
Horace Loomis	W. E. Belknap	Austin Lord Bowman
Josiah A. Briggs	Geo. C. Clarke	Alfred Craven
Allen Hazen	Rudolph Hering	George A. Just
Geo. W. Kittredge	Nelson P. Lewis	Geo. W. McNulty
C. H. Myers	Jos. O. Osgood	James Owen
Robert Ridgway	M. R. Sherrerd	Chas. W. Staniford
H. G. Stott	Geo. W. Tillson	T. Kennard Thomson
S. C. Thompson	John G. Van Horne	Francis Lee Stuart
D. J. Whittemore	Thos. C. Keefer	Alfred Noble
Geo. H. Benzenberg	Chas. Macdonald	Mendes Cohen
G. S. Greene, Jr.	F. S. Curtis	S. Whinery
Charles L. Strobel	Chas. D. Marx	Emil Swensson
Geo. S. Davison	Thos. H. Johnson	C. S. Churchill
Foster Crowell	W. G. Wilkins	C. F. Loweth
George Gibbs	Ralph Modjeski	Wm. J. Wilgus
R. S. Buck	Wm. Barclay Parsons	Albert B. Hill
C. E. Grunsky	Emil Kuichling	John F. O'Rourke
W. A. Cattell	S. H. Hedges	Wm. Cain
Charles Sooysmith	H. R. Leonard	Geo. S. Webster
Edgar B. Van Winkle	P. H. Norcross	D. W. Bliem
Wm. D. Janney	W. A. Nial	R. B. Kenrick
Layton F. Smith	A. V. Gude, Jr.	R. A. Polhamus
Wm. H. Dorsey	G. R. Solomon	F. P. Shearwood
J. Wilson Richardson	Warren E. Hall	A. T. Tomlinson
F. C. Wolf	R. M. Clayton	J. A. Jamieson
R. L. Chamberlaine	Wm. A. Hansell, Jr.	Phelps Johnson
Emory Sudler	Jas. Nisbet Hazlehurst	C. H. Keefer
B. F. Fendall	Wm. C. Spiker	Sandford Fleming
W. W. Crosby	H. W. Beers	W. H. Breithaupt
Ezra B. Whitman	B. M. Hall	S. J. Chapleau
T. K. Flick	E. E. Seyfert	C. R. F. Coutlee
Thos. D. Pitts	Park A. Dallis	A. R. Dufresne
Alfred H. Hartman	Nisbet Wingfield	K. M. Cameron
C. O. Vandevanter	Charles A. Caldwell	Chas. B. Wing
Harry D. Williar, Jr.	James J. Gaillard	E. T. Thurston, Jr.
J. W. Armstrong	Carl H. Fuller	Otto von Geldern
Oscar T. Lackey	Edw. E. Betts	J. H. Dockweiler
Wm. Anderson Polk	J. A. Fairleigh	B. P. Legaré
H. R. Talcott	D. H. Wood	H. T. Cory
H. A. Lane	W. H. Converse	J. M. Allen
M. A. Long	D. F. McCarthy	Stephen E. Kieffer
R. Reimann	D. M. Andrews	H. L. Haehl
E. G. Lane	Arthur Pew	Luther Wagoner

Discussion on Proposed Amendments (continued).

H. G. Shirley
R. N. Begien
Lester Bernstein
W. R. Edwards
P. G. Lang, Jr.
Paul Didier
B. P. Harrison
W. F. Strouse
A. W. Thompson
Wm. Mulholland
J. B. Lippincott
L. D. Blauvelt
Herbert S. Crocker
G. N. Houston
Arthur Ridgway
E. F. Vincent
I. O. Thorley
John A. Beeler
C. S. Lambie
Thomas L. Wilkinson
George G. Anderson
A. Lincoln Fellows
Charles W. Comstock
Joe Y. Work
D. G. Thomas
H. W. Cowan
H. F. Meryweather
C. C. Williams
M. S. Ketchum
H. E. Phelps
J. Y. Jewett
J. B. Hunter
T. W. Jaycox
Geo. M. Bull
Geo. L. Crawford
Cornelius B. Sampson
V. A. Kauffman
J. E. Maloney
John E. Field
Winfield Holbrook
F. T. Darrow
Robert Follansbee
M. C. Hinderlider
R. F. Walter
R. S. Sumner
J. R. Scott, Jr.
Chas. D. Vail
A. C. Dennis
Frank Lee
J. G. Sullivan
E. Brydone-Jack
C. S. MacCalla
W. G. Swendsen

C. M. Strahan
J. W. Barnett
John C. Koch
J. L. Meem
R. V. Rose
A. W. Pierson
H. J. Cowie
L. A. Pettebone
Chas. H. Moritz
Walter McCulloh
John L. Harper
W. W. Follett
J. L. Campbell
James A. French
W. G. Russell
H. J. Gault
F. H. Todd
E. H. Baldwin
Louis C. Hill
A. W. Cuddeback
John H. Cook
John W. Ferguson
J. E. Torrey
A. E. Schneeweiss
W. Wallace Christie
J. A. Nelson
Colin R. Wise
Chas. H. Miller
W. F. Reichardt
O. G. Baxter
W. D. Dickinson
Guy A. Watkins
Chas. J. Eld, Jr.
W. E. Ford
D. A. MacCrea
Philip B. Hill
Alfred M. Lund
E. A. Kingsley
P. R. Van Frank, Jr.
W. E. Price
A. S. Baldwin
J. B. Berry
E. S. Nethercut
H. E. Riggs
W. C. Hoad
Edward D. Rich
C. J. Tilden
L. M. Gram
H. B. Merrick
A. J. Decker
C. H. Cartlidge
Clarence T. Johnston
Chas. W. Spooner

W. H. Heuer
Hch. Homberger
J. Otis Burrage
F. C. Herrmann
H. H. Wadsworth
A. V. Saph
J. F. Murray
Saml. Rea
W. W. Atterbury
D. P. Pugh
E. B. Temple
H. C. Booz
C. W. Thorn
Robt. Farnham, Jr.
Joseph T. Richards
L. R. Zollinger
C. C. Anthony
R. G. Develin
J. T. Stuart
J. F. Cullen
P. F. Brendlinger
Percival M. Sax
Fred. W. Abbott
S. P. Mitchell
Wm. A. Moncure
Carl B. Ely
Paul L. Wölfel
Thomas Earle
Charles H. Mercer
Percy H. Wilson
Lewis R. Ferguson
Harold E. Hilts
Harrison W. Latta
Henry H. Quimby
Edwin Clark
Hermann V. Schreiber
Walter L. Fitzgerald
Emile G. Perrot
Walter F. Ballinger
Richard L. Humphrey
Wm. R. Webster
Samuel Tobias Wagner
Edwin F. Dawson
W. Hunter
Clark Dillenbeck
Percival S. Baker
Henry C. Smith
W. L. Stevenson
Ralph J. Lawrence
F. S. Stevens
W. B. Riegner
D. Jones Lucas
Edwin F. Smith

F. M. Carhart	T. L. Condron	Edgar Marburg
Geo. L. Swendsen	C. L. Post	Wm. Easby, Jr.
Thos. E. Brown	T. Lovel D. Hadwen	E. L. Ingram
Henry L. Lyon	A. G. Holt	H. C. Berry
S. M. Kielland	Alex. E. Kastl	Carleton E. Davis
Robert J. Reidpath	Wm. H. Yates	John S. Ely
Emile Low	Harry A. Weeks	Seth M. Van Loan
Edward B. Guthrie	H. J. Scheuermann	Edw. Gagel
Frank V. E. Bardol	C. H. Wood	L. J. Carmalt
C. M. Morse	A. W. Conner	Charles A. Ferry
D. A. Decrow	J. P. Newton	A. J. Du Bois
George A. Ricker	H. W. Benedict	Henry H. Gladding
George S. Minniss	W. E. Weller	C. W. Kelly
Henry J. Gardner, Jr.	I. S. Matlaw	Clarence M. Blair
J. C. Quintus	H. O. Schermerhorn	Charles Rufus Harte
J. F. Case	J. A. O'Connor	W. C. Watson
C. D. Pollock	W. A. Treadwell	W. J. Backes
A. M. Brosius	William R. Hill	D. W. McNaugher
William Francis	George T. Hammond	Geo. B. Palmer
Frank L. Getman	E. J. Fort	Jno. A. Ferguson
Enrique Ruiz Williams	H. H. Schmidt	W. M. Judd
Julio D. Montero	Willis R. Tenney	Edw. B. Taylor
Miguel Villa	J. Strachan	T. J. Wilkerson
Rafael Torralbas	J. C. Riedel	Robert A. Cummings
C. C. FitzGerald	Wm. Vallely	P. S. Perkins
Royal S. Webster	C. S. Haynes	A. H. Morrill
H. E. Hyde	Arthur J. Griffin	B. T. Wheeler
P. G. Cooper	Isaac A. Kirby	Virgil G. Bogue
A. C. Cunningham	Geo. Berry	Arthur H. Dimock
H. B. Hurlbut	K. L. Martin	A. Münster
P. L. Reed	George C. Whipple	Jesse A. Jackson
L. W. Page	Henry R. Asserson	Ernest B. Hussey
Paul D. Sargent	Charles H. Snow	Carl H. Reeves
Chas. H. Moorefield	Lardner V. Morris	S. Murray
Frank Sutton	J. E. Breen	S. B. Phillips
Sledge Tatum	I. M. de Varona	R. H. Ober
Hersey Munroe	Wm. W. Brush	C. A. D. Young
C. L. Sadler	H. B. Machen	Chas. Albertson
Vernon M. Peirce	W. Hauck	John C. Phillips
François E. Matthes	Edward L. Walker	D. W. McMorris
Leonard M. Cox	Joseph Goodman	Chas. C. More
Felix Freyhold	Elmer G. Manahan	A. T. Nelson
E. M. Douglas	Max Blatt	H. F. Tucker
J. H. Hanna	Matt. Quinn	Joseph Jacobs
A. P. Davis	Alfred S. Burgess	H. M. Chittenden
J. A. L. Waddell	Fred B. Nelson	Paul P. Whitham
D. E. McComb	W. F. Reeves	Phil. A. Franklin
C. B. Hunt	W. C. Merryman	Chauncy Wernecke
Asa E. Phillips	A. Boniface	J. W. Miller
Chester Harding	A. E. Olmsted	J. B. Warrack
T. J. Powell	Theodore Paschke	E. Gybbon Spilsbury
W. A. McFarland	Clarence W. Meyers	W. G. Triest
Frank M. Kerr	C. E. Carpenter	Clarence W. Hubbell

Discussion on Proposed Amendments (continued).

Donald D. Smith
Beverly R. Value
W. V. Judson
J. O. Whittemore
H. P. Gillette
Henry S. Wood
W. H. Arnold
Warren Gardner
A. W. Buel
C. H. Stengel
R. P. Staats
Edwin Thacher
Montgomery Waddell
W. S. Kinnear
Olaf Hoff
Philip W. Henry
A. L. A. Himmelwright
Geo. E. Gifford
Benjamin F. Welton
Kenneth Allen
E. H. Thomes
Herman K. Endemann
J. T. Fetherston
Theodor S. Oxholm
Paul G. Brown
H. E. Van Ness
A. E. Owen
A. M. Zabriskie
T. C. Fischer
H. D. Allen
M. Lewinson
Geo. L. Christy
Wm. J. Thomas
Virgil H. Hewes
Louis L. Brown
Holton D. Robinson
J. G. Theban
J. O. Eckersley
D. C. N. Collins
J. C. Ogden
R. C. Strachan
C. R. Hulsart
Alexander Johnson
H. A. La Chicotte
Leon S. Moisseiff
W. R. Bascome
J. I. Vincent
H. W. York
J. A. Knighton
Albin G. Nicolaysen
W. G. Yereance
C. E. Knickerbocker
C. L. Keller

D. C. Waite
F. W. Gardiner
Henry Leser
S. Johannesson
W. J. Boucher
Harold Tait
H. C. Hutchins
James C. Harding
Ned H. Sayford
James R. McClintock
George W. Fuller
H. C. Sanford
A. D Prince
John H. Madden
Chas. D. Searle
Geo. L. Lucas
A. B. Lueder
C. D. Thomas
Dean G. Edwards
Francis L. Pruyn
Jules Breuchaud
Chas. N. Green
Robert H. Jacobs
H. J. Alexander
C. V. V. Powers
R. P. Gustin
Edw. Pendlebury
A. J. Mayell
Frederick Wilcock
J. H. C. Gregg
Jules R. Breuchaud
Sverre Dahm
John H. Myers
F. E. Ferris
Frederick B. Barshell
Thad L. Wilson
Benjamin A. Hodgdon
M. H. Ryan
J. E. Jenkins
J. B. Goldsborough
David E. Baxter
Thaddeus Merriman
Merritt H. Smith
Fred T. Moore
Franklin H. Robbins
Clifford Seaver
Edgar F. Smith
James S. Harding
N. H. Janvrin
Alfred D. Flinn
Wilbur T. Wilson
H. Lincoln Rogers
Percy C. Barney

W. L. Saunders
A. A. Macdonald
Arthur H. Blanchard
G. S. Hubbell
Otto Sonne
W. G. Federlein
J. H. Staats
Alex. C. Humphreys
Stacy B. Opdyke, Jr.
George A. Soper
V. L. Havens
R. H. McPherson
H. de B. Parsons
Richard T. Dana
M. O. Eldridge
B. F. Cresson, Jr.
H. H. Farnum
Daniel Ulrich
Edward H. Holden
George T. Macnab
Nathaniel B. K. Hoffman
Richard H. Gillespie
Chas. Gartensteig
George Baum
W. H. Coverdale
W. W. Colpitts
Bernt Berger
Walton I. Aims
W. J. Haskins
Alex. G. Brinckerhoff
Owen Brainard
Charles W. Tarr
R. A. McCulloch
Charles H. Graham
Robert J. Beach
Frank P. Lant
W. F. Whittemore
Thos. H. McCann
C. D. Ward
Earl B. Lovell
E. De V. Tompkins
R. F. Almirall
C. W. Smith
M. A. Zook
S. W. Hoag, Jr.
U. S. Lutz
Philip Guise
R. T. Betts
W. J. Barney
Chas. E. Trout
Joel J. Pemoff
Geo. A. Taber
William B. Moss

Albert Carr
C. H. Stein
George Leighton
E. G. Haines
C. M. Holland
Joseph A. Connelly
W. F. Stevenson
Geo. S. Frost
Frederick C. Noble
H. L. Oestreich
Paul M. Entenmann
Harry L. Coyne
Chas. E. Conover
Arthur S. Tuttle
William G. Ford
Gustave Kaufman
C. A. Crane
Amos Schaeffer
Albert S. Crane
E. F. Robinson
Carlos Lobo
Robert H. Brown
Willard T. Chevalier
G. L. Christian
Geo. Hallett Clark
A. Sam'l Berquist
J. G. Basinger
D. H. Brown
A. H. Dakin, Jr.
J. J. Yates
W. H. Hunt
J. W. Hamilton
H. J. Chambers
J. L. Averill
A. L. Moorshead
Lewis D. Rights
S. B. Knox
W. R. Okeson
John T. Whistler
M. E. Reed
F. I. Fuller
Wm. S. Turner
Charles McGonigle
Garfield Stubblefield
Walter H. Graves
Orrin E. Stanley
Edwin A. Taylor
C. W. Raynor
D. D. Clarke
F. M. Randlett
Ernst Jonson
J. A. Lockwood
J. M. Stewart
A. A. Stuart
P. K. Yates
R. Walter Creuzbaur
Harry Hartwell
Frank Miller
J. S. Langthorn
Martin J. Ungrich
Walter E. Spear
Bertrand H. Wait
Neil C. Holdredge
C. J. O'Connor
Frank W. Allen
E. S. Brower
J. A. Lockwood
J. Van Vleck
J. W. Lieb
F. E. Caldwell
C. A. Van Keuren
N. D. Wortendyke
G. J. Ray
Geo. G. Honness
Fred K. Betts
Sidney K. Clapp
H. S. R. McCurdy
Geo. P. O'Connell
Winfred D. Hubbard
L. F. Searle
Eliot N. Smith
John L. Hildreth, Jr.
S. D. Dodge
M. E. Zipser
Frank L. Clapp
Jas. F. Sanborn
Ralph N. Wheeler
H. C. Paddock
Geo. H. Preston
A. W. Stephens
E. J. Moore
Archibald McLean
Elmer W. Firth
J. C. Meem
N. A. Carle
Robert A. Marshall
J. M. Schreiber
R. E. Danforth
T. M. Hurlburt
H. A. Benedict
J. H. Rostock
Henry N. Babcock
Harry R. Wheeler
J. E. Snell
Chandler Davis
L. C. Brink
Carleton Greene
Alexander Haring
George S. Baxter
Albert Lucius
Frank E. Winsor
Wilson Fitch Smith
Geo. A. Winsor
Wm. W. Peabody
Morton F. Sanborn
Carl P. Abbott
Chas. W. Leavitt, Jr.
Julian Richmond
T. F. Hickerson
R. G. Packard
Noah Cummings
Francis W. Perry
Martin Gay
Camille Mazeau
Geo. R. Ferguson
A. J. Malukoff
Louis Goodman
Jacob Thoma
R. G. Packard, Jr.
Thomas A. Allison
S. M. Swaab
R. E. Dougherty
E. J. Rights
Homer A. Reid
Herbert T. Rights
J. Wallace Higgins
E. M. T. Ryder
G. W. Swinburne
W. S. Menden
A. N. Spooner
George P. Wood
Charles S. Shaughnessy
Chester M. Gould
Warren F. Rugg
Andrew E. Foyé
H. R. Burroughs
Samuel Powers Connor
J. M. Hammer
W. H. Luster, Jr.
Teigi Ebashi"

Mr. Bensel.—In order that the atmosphere may be clarified and action taken at this meeting for changes in the Constitution, I

Discussion on Proposed Amendments (continued).

recommend that this amendment, along with the communication read by the Secretary, be referred to the Committee appointed by the Chair to consider the other amendments as proposed.

The motion was seconded and carried.

Formation of Philadelphia Association.

THE SECRETARY.—I have to announce for the information of the Meeting that a Philadelphia Association of Members of the Society has been formed, and that its Constitution is approved by the Board of Direction.

At a meeting of the Society, May 7th, 1913, the following resolution was adopted:

Announcements Regarding Appointment of Special Committees.

"MOVED: That the Board of Direction of the American Society of Civil Engineers be and is hereby authorized and directed to appoint a Special Committee to investigate the advisability of drafting a National Water Law applicable to all navigable, interstate and other waters within the jurisdiction of the United States, and embracing all uses of water, and that such committee be directed to prepare a preliminary draft of such a law for submission at some regular meeting of the Society, if, in their judgment, it appears advisable."

At the meeting of the Board, June 4th, 1913, the following resolution was passed:

"That it is the sense of the Board that such a Special Committee be appointed as soon as possible, and the Board will take up the appointment of this Committee in the near future."

At a meeting of the Society, May 7th, 1913, the following was adopted:

"RESOLVED: That the Board of Direction consider the matter of the appointment of a Special Committee to study the question of Floods, Flood Prevention and Other Allied Subjects."

At the meeting of the Board, June 4th, 1913, the following resolution was passed:

"That it is the sense of the Board that such a Special Committee be appointed as soon as possible, and the Board will take up the appointment of this Committee in the near future."

At the meeting of the Society, May 21st, 1913, the following resolution, suggested by W. P. Darwin, Assoc. M. Am. Soc. C. E., was presented:

"RESOLVED: That this Society appoint a Committee of five to prepare an Ideal Building Code to govern the general and essential features of construction of buildings in our American cities."

This matter was referred to the Board of Direction.

At its meeting of June 4th, 1913, the following resolution was adopted:

"That it is the sense of this Board that it is not advisable to appoint a Special Committee to prepare an Ideal Building Code to gov-

ern the general and essential features of construction of buildings in our American cities."

At the June 4th, 1913, Society Meeting the following motion was offered by J. P. Snow, M. Am. Soc. C. E.

"That it is the sense of this meeting that the American Society of Civil Engineers should appoint a Special Committee to act jointly with the American Railway Engineering Association in studying and experimenting on the stresses in railroad rails, ties, etc."

The motion, being duly seconded, was carried.

Mr. Snow moved, further:

"That the matter of appointing this Committee be left with the Board of Direction with full power."

This motion, being duly seconded, was carried.

The matter is therefore now in the hands of the Board of Direction, and is reported to this meeting as a matter of information.

THE PRESIDENT.—There is no action needed on these announcements by this meeting, but the Board would, of course, take any suggestions into consideration.

Letter from Mr. P. M. Churchill.

THE SECRETARY.—I have a communication here from Percival M. Churchill, Assoc. M. Am. Soc. C. E.

"42 Church Street, New Haven, Conn.
"June 14, 1913.

"*The Secretary,*
"American Society of Civil Engineers,
"No. 220 West Fifty-seventh Street,
"New York, N. Y.

"*Dear Sir:*—Will you kindly introduce the following motion for me at the Convention next week, as I shall not be able to attend:

"Moved: That the following questions be submitted to the members of this Society:

"1. Shall the Society *approve* or *disapprove* of the principle of regulating the practice of civil engineering through legislative enactment?

"2. In carrying out the will of the Society as expressed in question No. 1, shall the officers of the Society take an *active* or a *passive* attitude toward any such legislation when proposed in any State in the country?

"3. Shall the Society *approve* or *disapprove* of attempting to regulate the practice of civil engineering through rules of this and its allied Societies?

"4. Shall this Society, *with* or *without* the aid of the other National Engineer Societies, attempt to *outline* and to *put into practice* a plan for marketing engineering services of all grades?

"5. If the Society votes in the affirmative on question No. 4, shall the Officers of the Society be instructed and empowered to promptly, personally, or through a committee, carry out its provisions?

Letter from Mr. P. M. Churchill (continued.)

"If these questions are submitted to the members in the form here presented, a member may vote by crossing out the underlined word conveying a meaning of which he disapproves, and then answering the whole question, so amended, by 'Yes' or 'No.'

"Very respectfully,

"PERCIVAL M. CHURCHILL,

"Assoc. M. Am. Soc. C. E."

Announcement Regarding International Engineering Congress.

The communication, on motion, was referred to the Board of Direction.

THE SECRETARY.—I want to make a brief announcement concerning the International Engineering Congress to be held in connection with the Panama-Pacific International Exposition in 1915 in San Francisco. This Congress has been underwritten by and is to be conducted under the auspices of the five National Engineering Societies, and its organization is now going forward rapidly. It is hoped and expected that there will be a large attendance, especially of members of this Society. (Applause.)

On motion the meeting was then adjourned.

FORTY-FIFTH ANNUAL CONVENTION

EXCURSIONS AND ENTERTAINMENTS

The arrangements were in the hands of the following Committees:

Committee of Arrangements of the Board of Direction

CHARLES H. RUST, *Chairman;*

HENRY W. HODGE, CHAS. WARREN HUNT.

Local Committee

CHAS. H. KEEFER, *Chairman;*

W. H. BREITHAUPT,
S. J. CHAPLEAU,
C. R. F. COUTLEE,
A. R. DUFRESNE,
G. H. DUGGAN,
Sir SANDFORD FLEMING,
H. HOLGATE,
J. A. JAMIESON,
PHELPS JOHNSON,
T. C. KEEFER,
H. G. KELLEY,
JOHN KENNEDY,
WILLIAM MCNAB,
C. H. MITCHELL,
H. R. SAFFORD,
W. F. TYE,
G. W. VOLCKMAN.

Informal Receptions

Tuesday, June 17th, 1913.—3 P. M.—The Society was welcomed at the Chateau Laurier by the Hon. Martin Burrell, Minister of Agriculture, representing the Government of Canada in the unavoidable absence of the Premier, the Right Hon. R. L. Borden; also by the Mayor of Ottawa, J. A. Ellis, Esq. An address in reply was made by George F. Swain, President of the Society.*

Tuesday, June 17th, 1913.—9 P. M.—The President and officers of the Society held an Informal Reception at the Chateau Laurier which was attended by a large number of members and guests. The reception was followed by dancing.

Luncheons and Lectures

Wednesday, June 18th.—The ladies attending the Convention were entertained at luncheon at the Royal Ottawa Golf Club by the ladies of the Local Committee.

At the conclusion of the Business Meeting a large number of the members attended a luncheon at the Chateau Laurier given by the Ottawa Branch of the Canadian Society of Civil Engineers.

At the invitation of T. C. Keefer, C. M. G., Past-President, Am. Soc. C. E., the members and their guests were present at a Garden Party given at his residence, the Manor House, Rockcliffe Park, from 4 P. M. to 7 P. M.

* A report in full of these speeches will be found on page 419.

In the evening at the Chateau Laurier the members had the pleasure of hearing illustrated lectures on Canadian engineering subjects. David A. Molitor, M. Am. Soc. C. E., described Proposed Improvements of the Toronto Harbor Works; C. R. F. Coutlee, M. Am. Soc. C. E., the Water Transportation Routes of Canada; Mr. R. F. Uniacke, the Transcontinental Railways; and Mr. J. B. Challies, the Water Powers of the Dominion.

Drive and Afternoon Tea

Thursday, June 19th.—Leaving the headquarters at 2 P. M., the members and their guests were driven through the city, visiting the principal points of interest, including the Government House, Royal Mint, Parliament House, Victoria Memorial Museum, Headquarters of the Geological Survey of Canada, and Dominion Government Experimental Station.

At the end of the drive a large number were entertained at afternoon tea by Mrs. Collingwood Schreiber at her home on Argyle Street.

Reception

Thursday, June 19th.—In the evening a reception was given by the Ottawa Branch of the Canadian Society of Civil Engineers to the members of the American Society of Civil Engineers and accompanying ladies. The reception was largely attended and was followed by dancing, which continued until 2.30 A. M.

Excursion to Montreal

Friday, June 20th.—The Grand Trunk Railway, through H. G. Kelley, M. Am. Soc. C. E., Vice-President, and H. R. Safford, M. Am. Soc. C. E., Chief Engineer, provided a special train to Montreal for all those who wished to accept the invitation of the Montreal members of the Local Committee to visit the points of interest in that city. About 100 members and guests took this train, which arrived in Montreal about noon. Most of the party then boarded a steamer furnished by the Dock Commissioners of Montreal, and more than three hours were spent in viewing the harbor, a visit being made to a reinforced concrete grain elevator recently placed in operation, and also to a floating dry dock, on which a vessel was in place for repairs. Luncheon was served on board the steamer. Upon returning to the dock the party proceeded by special observation car entirely around the city, thus giving an excellent opportunity to view the principal points of interest.

A number of the party availed themselves of the opportunity afforded by S. P. Brown, M. Am. Soc. C. E., to visit the Mount Royal Tunnel of the Canadian Northern Railroad, now under construction. A visit was also made by some of the members to the new shops of

the St. Lawrence Bridge Company, where, through the courtesy of Phelps Johnson, M. Am. Soc. C. E., an opportunity was given to make a thorough inspection.

Excursion to Britannia Park

Friday, June 20th.—Those members of the Society who remained in Ottawa participated in an excursion to Queen's Park, *via* the Hull Electric Railway, thence by steamer for a short trip to Lake Deschene, crossing over to Britannia Park, and returned to Ottawa *via* the Ottawa Electric Railway.

Attendance

The following 138 members were in attendance. There were also present 207 ladies and others of the families of members.

Babcock, W. S....New York City
Baker, I. O..........Urbana, Ill.
Baldwin, A. S.......Chicago, Ill.
Ball, C. B...........Chicago, Ill.
Barbour, F. A......Boston, Mass.
Bates, Onward.......Chicago, Ill.
Begg, R. B. H....Lawrence, Kans.
Bensel, J. A.......Albany, N. Y.
Beugler, E. J.....New York City
Bouillon, A. M......Quebec, Que.
Brace, J. H.........Cedars, Que.
Brackett, Dexter....Boston, Mass.
Breed, C. B........Boston, Mass.
Breithaupt, W. H....Berlin, Ont.
Brook, A. E........Toronto, Ont.
Brooks, J. P......Potsdam, N. Y.
Brown, S. P.......Montreal, Que.
Brush, W. W....New York City
Buel, A. W.......New York City
Burpee, G. W.....New York City
Burt, H. J...........Chicago, Ill.

Cameron, K. M.....Ottawa, Ont.
Christian, W. A......Chicago, Ill.
Clarke, G. C......New York City
Coleman, J. F...New Orleans, La.
Connelly, J. A....New York City
Cotton, J. P.......Newport, R. I.
Coutlee, C. R. F.....Ottawa, Ont.

Darrow, W. J.....New York City
Davis, C. M......Ft. Worth, Tex.
Deyo, S. L. F.....New York City
Dibert, H. McM......Troy, N. Y.
Doty, J. W........Montreal, Que.
Duggan, G. H.....Montreal, Que.
Dunn, D. B...........Macon, Ga.

Eddy, H. P.........Boston, Mass.
Edwards, L. N......Toronto, Ont.
Ellis, J. W.....Woonsocket, R. I.
Endicott, M. T..Washington, D. C.

Fay, F. H..........Boston, Mass.
Fisher, E. A.....Rochester, N. Y.
Fraser, C. E......New York City
Fuller, W. E.....New York City

Gahagan, W. H..Brooklyn, N. Y.
Going, A. S.......Montreal, Que.

Haring, Alexander, New York City
Hawley, G. P........Cedars, Que.
Hazen, Allen.....New York City
Heckle, G. R......Montreal, Que.
Hering, Rudolph..New York City
Hoag, S. W., Jr..New York City
Holgate, Henry....Montreal, Que.
Hopkins, C. C...Rochester, N. Y.
Howard, C. P........Chicago, Ill.
Humphreys, D. C..Lexington, Va.
Hunt, Chas. Warren, New York City

Jamieson, J. A....Montreal, Que.
Johnson, Phelps...Montreal, Que.
Jones, H. L.......New York City

Kastl, A. E. . . . . Albany, N. Y.
Keefer, T. C. . . . . Ottawa, Ont.
Keefer, C. H. . . . . Ottawa, Ont.
Kennedy, John. . . . Montreal, Que.
Kerr, F. M. . . . . New Orleans, La.
King, P. S. . . . . Wilmington, Del.
Kinney, W. M. . . . Pittsburgh, Pa.

Landreth, O. H., Schenectady, N. Y.
Larner, C. W. . . . . Cleveland, Ohio
LeDuke, J. C. . . . . Toledo, Ohio
Leonard, H. R. . Philadelphia, Pa.
Lewis, E. W. . . New Haven, Conn.
Loomis, Horace. . . New York City
Loweth, C. F. . . . . Chicago, Ill.
Lowinson, Oscar. . New York City

Macdonald, Charles, New York City
McKenzie, T. H., Southington, Conn.
McLachlan, D. W. . . . Ottawa, Ont.
McNab, William. . . Montreal, Que.
McRae, J. B. . . . . Ottawa, Ont.
Main, C. T. . . . . Boston, Mass.
Mayer, Joseph. . . . . Montreal, Que.
Mehren, E. J. . . . . . New York City
Metcalf, Leonard. . . . Boston, Mass.
Mitchell, C. H. . . . . . Toronto, Ont.
Mitchell, S. P. . Philadelphia, Pa.
Modjeski, Ralph. . . . . Chicago, Ill.
Molitor, D. A. . . . . . . Toronto, Ont.
Monsarrat, C. N. . . Montreal, Que.
Morssen, C. M. . . . . Montreal, Que.
Murray, J. F. . . . Philadelphia, Pa.

O'Brien, J. H. . . . . Montreal, Que.
Ockerson, J. A. . . . . St. Louis, Mo.
Owen, A. E. . . . . . Montclair, N. J.
Owen, James. . . . . . Newark, N. J.

Pegram, G. H. . . . New York City
Pense, E. H. . . . . Ottawa, Ont.
Perkins, E. T. . . . . . . Chicago, Ill.
Purdy, C. T. . . . . . New York City

Richardson, J. H. . . Boston, Mass.
Ricker, G. A. . . . . . Albany, N. Y.
Ridgway, Robert. . New York City
Riggs, M. J. . . . . Toledo, Ohio
Robinson, A. W. . . Montreal, Que.
Rourke, L. K. . . . . . . Boston, Mass.

Safford, H. R. . . . . . Montreal, Que.
Sargent, C. D. . . . . Cornwall, Ont.
Scammell, J. H. . Saint John, N. B.
Schneider, C. C. . Philadelphia, Pa.
Seaman, H. B. . . . New York City
Skinner, F. W. . . . New York City
Slocum, H. S. . . . . Cedars, Que.
Smith, J. Waldo. . New York City
Smith, M. H. . . . . New York City
Smith, Oberlin. . . Bridgeton, N. J.
Solomon, G. R. . . . . . . Atlanta, Ga.
Sperry, L. N. . Tupper Lake, N. Y.
Spofford, C. M. . . . . Boston, Mass.
Stearns, F. P. . . . . . . Boston, Mass.
Strachan, Joseph. . Brooklyn, N. Y.
Swain, G. F. . . . Cambridge, Mass.

Talbot, A. N. . . . . Urbana, Ill.
Thomas, R. D. . Minneapolis, Minn.
Thomson, S. F. . New Paltz, N. Y.
Thomson, T. K. . . . New York City
Tighe, J. L. . . . . . . Holyoke, Mass.
Tomlinson, A. T. . . Montreal, Que.
Tucker, L. W. . . . . New York City

Van Cleve, A. H. . New York City
Van Horne, J. G. . New York City
Van Norden, E. M., Brooklyn, N. Y.
Van Suetendael, A. O., Albany, N. Y.
Volckman, G. W. . . . Ottawa, Ont.

Weston, R. S. . . . . . . Boston, Mass.
White, Lazarus. . . New York City
Wiley, W. H. . East Orange, N. J.
Williams, G. S. . Ann Arbor, Mich.
Wisner, G. M. . . . . Chicago, Ill.

Yappen, Adolph. . . . . Chicago, Ill.

ANNOUNCEMENTS

The House of the Society is open from 9 A. M. to 10 P. M., every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

FUTURE MEETINGS

September 3d, 1913.—8.30 P. M.—A regular business meeting will be held, and two papers will be presented for discussion, as follows: "The Storage of Flood Waters for Irrigation: A Study of the Supply Available from Southern California Streams," by A. M. Strong, Assoc. M. Am. Soc. C. E.; and "Modern Pier Construction in New York Harbor," by Charles W. Staniford, M. Am. Soc. C. E.

These papers were printed in *Proceedings* for May, 1913.

September 17th, 1913.—8.30 P. M.—At this meeting a paper by J. C. Ulrich, M. Am. Soc. C. E., entitled "The Prewitt Reservoir Proposition," will be presented for discussion.

This paper was printed in *Proceedings* for May, 1913.

October 1st, 1913.—8.30 P. M.—A regular business meeting will be held, and a paper by William J. Wilgus, M. Am. Soc. C. E., entitled, "Physical Valuation of Railroads," will be presented for discussion.

This paper was printed in *Proceedings* for May, 1913.

October 15th, 1913.—New Orleans Meeting.—The Meeting of the Society scheduled for October 15th, 1913, will be held in New Orleans, La., and a paper by W. E. Fuller, M. Am. Soc. C. E., entitled "Flood Flows," will be presented for discussion. Mr. Fuller's paper was printed in *Proceedings* for May, 1913.

In connection with this Meeting the Louisiana Members have arranged a programme covering Wednesday, Thursday, Friday, and Saturday, October 15th to 18th, inclusive, and it is hoped that there will be a large attendance of the members and the ladies of their families.

A circular containing general information, and the proposed programme, hotel rates, etc., has already been mailed to all members.

November 5th, 1913.—8.30 P. M.—This will be a regular business meeting. Two papers will be presented for discussion, as follows: "Concrete Bridges: Some Important Features in Their Design," by Walter M. Smith, Sr., M. Am. Soc. C. E., and Walter M. Smith, Jr., Jun. Am. Soc. C. E.; and "The Effect of Saturation on the Strength of Concrete," by J. L. Van Ornum, M. Am. Soc. C. E.

These papers are printed in this number of *Proceedings*.

SEARCHES IN THE LIBRARY

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

In reference to this work, the Appendices* to the Annual Reports of the Board of Direction for the years ending December 31st, 1906, and December 31st, 1910, contain summaries of all searches made to date.

PAPERS AND DISCUSSIONS

Members and others who take part in the oral discussions of the papers presented are urged to revise their remarks promptly. Written communications from those who cannot attend the meetings should be sent in at the earliest possible date after the issue of a paper in *Proceedings*.

All papers accepted by the Publication Committee are classified by the Committee with respect to their availability for discussion at meetings.

Papers which, from their general nature, appear to be of a character suitable for oral discussion, will be published as heretofore in *Proceedings*, and set down for presentation to a future meeting of the Society, and, on these, oral discussions, as well as written communications, will be solicited.

All papers which do not come under this heading, that is to say, those which from their mathematical or technical nature, in the opinion of the Committee are not adapted to oral discussion, will not be scheduled for presentation to any meeting. Such papers will be published in *Proceedings* in the same manner as those which are to be presented at meetings, but written discussions, only, will be re-

* *Proceedings*, Vol. XXXIII, p. 20 (January, 1907); Vol. XXXVII, p. 28 (January, 1911).

quested for subsequent publication in *Proceedings* and with the paper in the volumes of *Transactions*.

The Board of Direction has adopted rules for the preparation and presentation of papers, which will be found on page 429.

LOCAL ASSOCIATIONS OF MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

San Francisco Association

The San Francisco Association of Members of the American Society of Civil Engineers holds regular bi-monthly meetings, with banquet, and weekly informal luncheons. The former are held at 6 P. M., at the Palace Hotel, on the third Friday of February, April, June, August, October, and December, the last being the Annual Meeting of the Association.

Informal luncheons are held at 12.15 P. M. every Wednesday, and the place of meeting may be ascertained by communicating with the Secretary of the Association, E. T. Thurston, Jr., M. Am. Soc. C. E., 713 Mechanics' Institute, 57 Post Street.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in San Francisco, and any such member will be gladly welcomed as a guest.

(Abstract of Minutes of Meeting)

April 18th, 1913.—The meeting was called to order; Vice-President C. H. Snyder in the chair; E. T. Thurston, Jr., Secretary; and present, also, 85 members and guests.

The meeting was addressed by Jerome Newman, M. Am. Soc. C. E., the subject being "The Development of Wharf Construction in San Francisco Bay."

Adjourned.

Colorado Association

The meetings of the Colorado Association of Members of the American Society of Civil Engineers are held on the second Saturday of each month, except July and August. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary, R. W. Toll, Jun. Am. Soc. C. E., 700 Tramway Building, Denver, Colo. The meetings are usually preceded by an informal dinner. Members of the American Society of Civil Engineers will be welcomed at these meetings.

Weekly luncheons are held on Wednesdays, and, until further notice, will take place at the Colorado Traffic Club.

Visiting members are urged to attend the meetings and luncheons.

(Abstract of Minutes of Meetings)

May 10th, 1913.—The meeting was called to order at 8.30 P. M.; President Ketchum in the chair; G. N. Houston, Secretary; and present, also, 18 members and 11 guests.

The minutes of the meeting of April 12th, 1913, were read and approved.

The President appointed the following Nominating Committee: Messrs. H. S. Crocker, *Chairman,* George G. Anderson, H. W. Cowan, W. Holbrook, and L. E. Bishop.

A resolution relative to the endorsement of John B. Hunter, M. Am. Soc. C. E., for the office of Commissioner of Improvements of the City and County of Denver, was read and adopted unanimously.

The Final Report of the Legislative Committee was read and approved.

George G. Anderson, M. Am. Soc. C. E., presented a paper on the "Panama Canal," illustrating his remarks with stereopticon views, and the subject was discussed by Messrs. Frederick S. Titsworth, D. W. Brunton, James R. Thorp, H. W. Knowlton, and others.

Adjourned.

June 14th, 1913.—The Annual Meeting was called to order; President Ketchum in the chair; G. N. Houston, Secretary; and present, also, 10 members and 1 guest.

The President read his Annual Address. This was followed by the Annual Report of the Secretary-Treasurer.

A paper by J. Y. Jewett, Assoc. M. Am. Soc. C. E., entitled "Tests of Concrete Materials," was presented by the author, and the subject was discussed by those present at the meeting.

Messrs. T. W. Jaycox and R. F. Walter were appointed Tellers to canvass the ballot for the election of officers, and President Ketchum announced the result, as follows:

President, G. N. Houston,
Vice-President, A. O. Ridgway,
Secretary-Treasurer, R. W. Toll.

Adjourned.

Atlanta Association

On March 14th, 1912, the Atlanta Association of Members of the American Society of Civil Engineers was organized, with the following officers: Arthur Pew, President; William A. Hansell, Jr., Secretary; and Messrs. James N. Hazlehurst and Alexander Bonnyman, Members of the Executive Committee. The Association will hold its meetings in the house of the University Club.

Philadelphia Association

At its meeting of June 4th, 1913, the Board of Direction of the Society considered and approved the proposed Constitution of the Philadelphia Association of Members of the American Society of Civil Engineers.

Seattle Association

On June 30th, 1913, the Seattle Association of Members of the American Society of Civil Engineers was organized with the following officers: Samuel H. Hedges, President; Ernest B. Hussey, Vice-President; and Joseph Jacobs, Secretary-Treasurer.

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms, and at all meetings:

American Institute of Mining Engineers, 29 West Thirty-ninth Street, New York City.

American Society of Mechanical Engineers, 29 West Thirty-ninth Street, New York City.

Architekten-Verein zu Berlin, Wilhelmstrasse 92, Berlin W. 66, Germany.

Associagão dos Engenheiros Civis Portuguezes, Lisbon, Portugal.

Australasian Institute of Mining Engineers, Melbourne, Victoria, Australia.

Boston Society of Civil Engineers, 715 Tremont Temple, Boston, Mass.

Brooklyn Engineers' Club, 117 Remsen Street, Brooklyn, N. Y.

Canadian Society of Civil Engineers, 413 Dorchester Street, West, Montreal, Que., Canada.

Civil Engineers' Society of St. Paul, St. Paul, Minn.

Cleveland Engineering Society, Chamber of Commerce Building, Cleveland, Ohio.

Cleveland Institute of Engineers, Middlesbrough, England.

Dansk Ingeniorforening, Amaliegade 38, Copenhagen, Denmark.

Engineers' and Architects' Club of Louisville, Ky., 303 Norton Building, Fourth and Jefferson Streets, Louisville, Ky.

Engineers' Club of Baltimore, Baltimore, Md.

Engineers' Club of Minneapolis, 17 South Sixth Street, Minneapolis, Minn.

Engineers' Club of Philadelphia, 1317 Spruce Street, Philadelphia, Pa.

Engineers' Club of St. Louis, 3817 Olive Street, St. Louis, Mo.

Engineers' Club of Toronto, 96 King Street, West, Toronto, Ont., Canada.

Engineers' Society of Northeastern Pennsylvania, 302 Board of Trade Building, Scranton, Pa.

Engineers' Society of Pennsylvania, 219 Market Street, Harrisburg, Pa.

Engineers' Society of Western Pennsylvania, 2511 Oliver Building, Pittsburgh, Pa.

Institute of Marine Engineers, 58 Romford Road, Stratford, London, E., England.

Institution of Engineers of the River Plate, Buenos Aires, Argentine Republic.

Institution of Naval Architects, 5 Adelphi Terrace, London, W. C., England.

Junior Institution of Engineers, 39 Victoria Street, Westminster, S. W., London, England.

Koninklijk Instituut van Ingenieurs, The Hague, The Netherlands.

Louisiana Engineering Society, 321 Hibernia Bank Building, New Orleans, La.

Memphis Engineering Society, Memphis, Tenn.

Midland Institute of Mining, Civil and Mechanical Engineers, Sheffield, England.

Montana Society of Engineers, Butte, Mont.

North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne, England.

Oesterreichischer Ingenieur- und Architekten-Verein, Eschenbachgasse 9, Vienna, Austria.

Pacific Northwest Society of Engineers, 803 Central Building, Seattle, Wash.

Rochester Engineering Society, Rochester, N. Y.

Sachsischer Ingenieur- und Architekten-Verein, Dresden, Germany.

Sociedad Colombiana de Ingenieros, Bogota, Colombia.

Sociedad de Ingenieros del Peru, Lima, Peru.

Societe des Ingenieurs Civils de France, 19 Rue Blanche, Paris, France.

Society of Engineers, 17 Victoria Street, Westminster, S. W., London, England.

Svenska Teknologforeningen, Brunkebergstorg 18, Stockholm, Sweden.

Tekniske Forening, Vestre Boulevard 18–1, Copenhagen, Denmark.

Western Society of Engineers, 1737 Monadnock Block, Chicago, Ill.

ACCESSIONS TO THE LIBRARY

(From May 5th to July 31st, 1913)

DONATIONS*

PRINCIPLES OF IRRIGATION ENGINEERING:

Arid Lands, Water Supply, Storage Works, Dams, Canals, Water Rights, and Products. By Frederick Haynes Newell and Daniel William Murphy, Members, Am. Soc. C. E. Cloth, 9½ x 6¼ in., illus., 13 + 293 pp. New York and London, McGraw-Hill Book Company, 1913. $3.00.

The preface states that the title of this book has been selected as indicative of its scope, irrigation engineering being defined as the development of the water resources of the arid regions with regard to their conservation and use and as dealing with methods of holding, controlling, and distributing the waters needed in agriculture and other matters which lead to financial success in investments made therein. The authors state that while this book is intended primarily for the use of students and engineers who desire to become acquainted with the general principles involved in considering the feasibility of, and in designing, constructing, and operating, irrigation systems, the broader and more general aspects of the subject have been presented in such a manner as to attract the reader who is interested in irrigation, but without any technical knowledge of hydraulics. The Contents are: Irrigation; Irrigable Lands; Water Supply; Design and Construction of Canals; Canal Structures; Distribution Systems; Irrigation by Pumping; Drainage; Operation and Maintenance; Storage Works; Reservoir Sites; Dam Sites; Timber Dams; Earth Dams; Rock-Fill Dams; Masonry Dams; Outlet Works; Water Rights; Economic Features of Irrigation; Index.

THE IMPROVEMENT OF RIVERS:

A Treatise on the Methods Employed for Improving Streams for Open Navigation, and for Navigation by Means of Locks and Dams. By B. F. Thomas and D. A. Watt, Members, Am. Soc. C. E. Second Edition, Rewritten and Enlarged. Cloth, 12 x 9½ in., illus., 2 vol. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Limited, 1913. $6.00.

The first edition of this work was published in 1903 to meet, it is stated, the needs of engineers and others engaged in the improvement of rivers, information on the subject at that time being confined to Government reports and technical publications. That edition included the theory, as well as descriptions, of all the points of design and construction for such work, together with calculations, etc., with the hope that the book would prove of interest not only to engineers but to inspectors, surveyors, etc. In this, the second edition, the subject-matter, it is said, has been entirely rewritten and rearranged, and while much new matter, including costs and many drawings, has been added, especially in that portion treating of open-river navigation which has been revised to include the latest practice in this country and abroad, much of the detailed matter relating to discharge, rainfall, and run-off, methods of gauging, surveys, etc., readily found elsewhere, has been omitted. The Contents are: Part I, Improvement by Regulation: Characteristics of Rivers; Regulation; Dredging and Snagging; Dikes; Protection of Banks; Levees; Storage Reservoirs; The Improvement of the Outlets of Rivers. Part II, Improvement by Canalization: General Design and Construction of Locks and Dams; Locks; Lock Gates and Valves; Fixed Dams; Movable Dams; Needle Dams; Chanoine Wicket-Dams; Gate and Curtain Dams, Bridge and Shutter Dams; Drum Wickets, Bear-Traps, and Rolling Dams; Accidents to Structures, etc.; Tables of Locks and Dams; Waterways in Europe and Elsewhere; Index.

THE MODERN WARSHIP.

By Edward L. Attwood. (The Cambridge Manuals of Science and Literature.) Cloth, 6¾ x 5 in., illus., 7 + 146 pp. Cambridge, University Press; New York, G. P. Putnam's Sons, 1913. 40 cents.

This book contains, it is stated, a brief account of the details of constructing a modern English warship, written from the viewpoint of the naval architect for the

* Unless otherwise specified, books in this list have been donated by the publishers.

general reader who desires to obtain some knowledge of the subject. Many points of interest in connection with warship design and construction have been omitted, the author states, owing to limited space. Nothing of a controversial or confidential nature is included, nor is there any reference to contemporary warships of other countries. The Contents are: Design; Hull Construction; Armour; Armament; Equipment; Stability and Rolling; Engines, Boilers, etc.; Ventilation and Pumping; Watertight Subdivision; Steering and Turning; Power and Speed; The Cost of Warships; Bibliography; Index.

THE CIVIC ENGINEER'S WHO'S WHO.

Compiled by the Editor of *The Surveyor and Municipal and County Engineer*. First (1912) Annual Issue. Paper, 7¼ x 5 in., 120 pp. London, St. Bride's Press, Ltd., 1912. 60 cents.

The biographies given in this volume include only those of civic engineers of Great Britain. No attempt has been made, it is stated, in this, the first issue of this work, to make the biographies comprehensive, the only ones given with any degree of completeness being those of engineering officials of the County Councils and Municipal Corporations of England and Wales, the Metropolitan Borough Councils, and the District Surveyors of London.

RIVERS AND ESTUARIES;

Or, Streams and Tides: An Elementary Study. By W. Henry Hunter, M. Am. Soc. C. E. Cloth, 9½ x 6 in., illus., 69 pp. London, New York, Bombay, and Calcutta, Longmans, Green and Co., 1913. $1.00. (Donated by the Author.)

This work, it is stated, is based, to a large extent, on lectures on the subject delivered by the author in 1911, under the Vernon-Harcourt Bequest, before the Students of the Institution of Civil Engineers in various parts of Great Britain, and also in lectures on "Streams and Tides" delivered before the students of the Department of Engineering of the University of Manchester. The subject-matter, it is further stated, and as defined in the title, is an elementary study of rivers and estuaries, in which the author, from his wide experience, has described the difficulties of the question, physical and otherwise, the regimen of rivers, the velocities of flow, mouths of rivers, etc., together with examples of successes and failures in river improvement in various parts of the world, for the benefit of students and young engineers. The Contents are: Difficulties of the Subject; Physical Difficulties; The Pursuit of Information; Flow Round Bends; The Mouth of the River; River Improvement Works; Estuarial Works; Some European Examples; Some American Examples; The Mersey; Estuarial Models; Index.

PRACTICAL ALTERNATING CURRENTS AND ALTERNATING CURRENT TESTING.

By Charles F. Smith. Fifth Edition. Cloth, 9 x 6 in., illus., 15 + 398 pp. Manchester, England, The Scientific Publishing Company. 6 shillings.

The author's aim has been, it is stated, to produce in this volume, and from an experimental standpoint, a textbook on the main principles of alternating currents and alterating-current machinery, as well as a reference book for the laboratory and test house. The experiments are stated to be described in detail and may be taken as a general outline for a course in practical work in the laboratory. The use of the higher mathematics in the text has been avoided, except in a few instances, and treatment based on actual results and examples has been used as far as possible. This new edition has been carefully revised, it is stated, and a number of alterations and additions have been made. The Contents are: Alternating Electromotive Force and Current; Impedance; Power and Power-Factor; Virtual Value of an Alternating Current; Effect of Capacity; The Transformer; Alternaters; Synchronous Motors; The Polyphase Circuit; The Rotary Converter; The Polyphase Induction Motor; Single-Phase Motors; The Composition of Waves; Index.

MECANIQUE, ELECTRICITÉ, ET CONSTRUCTION APPLIQUÉES AUX APPAREILS

De Levage: Tome II, Les Ponts Roulants à Treillis et les Grues à Portiques Actuels. Par Louis Rousselet. Paper, 11¼ x 7½ in., illus., 6 + 752 pp. Paris, H. Dunod et E. Pinat, 1913. 45 francs.

In the first volume of this work, which was devoted wholly to traveling cranes, the subject-matter, it is stated, related to the type constructed by the author and to the theories and conditions which led to the rapid working out of his plans, esti-

mates, and details of construction. In this second volume various types of apparatus, as well as the details of their construction, are described, 238 pages being devoted to brakes and couplings and to numerous calculations of the principal systems, which alone is stated to justify the publication of this new volume. In addition to a detailed study of the framework of lattice traveling cranes and of gantry cranes, the subject-matter contains studies of aerial tramways, foundations, etc., which should be useful to the engineer in the installation of such cranes. Descriptions and specifications of numerous types of traveling and gantry cranes, particularly of those used in steelworks, are also given. The Contents are: Part I, Généralités; Moteurs. Part II, Engrenages Divers; Trains d'Engrenages; Classification des Treuils. Part III, Freins a Main ou a Pédale et Freins Fonctionnant Independamment du Moteur Embrayages et Changements de Vitesse. Part IV, Freins Dont le Fonctionnement est Indissolublement Lie a la Marche du Moteur Part V, Vis Sans Fin; Reducteurs. Part VI, Chaines; Cables; Tambours; Suspensions. Part VII, Moufles et Palans. Part VIII, Opérateurs. Part IX, Direction, Translation. Chariots Roulants. Part X, Charpente de Ponts et Portiques Roulants a Treillis. Part XI, Specifications et Descriptions d'Appareils Construits; Appendice.

COST REPORTS FOR EXECUTIVES

As a Means of Plant Control. By Benj. A. Franklin. Cloth, $8\frac{3}{4}$ x $5\frac{1}{2}$ in., illus., 149 pp. New York, The Engineering Magazine Co., 1913. $5.00.

The object of this book, as stated in the preface, is to discuss with the executive of a manufacturing plant what he should have when his cost system is built, the values, the uses, and the essential necessities of a practical cost system, showing the operations of his material, labor, and expenses, and their relations to each other, and, in order to make such a system clear, to illustrate it with practical forms. Only the main points of the subject are said to be covered, and the forms are not applicable to any particular business, merely illustrating the principles, but the author hopes that a study of his book will lead to knowledge of cost systems as an essential requirement on the part of future managers and executives. The Chapter headings are: The Philosophy of Costs; The Place of the Trial Balance in the Cost System; The Cost of the Salable Article; The Economic Consideration of Material by Costs; Labor from the Cost Viewpoint; The Vexing Question of Expense; Statistics as an Aid; Cost System—The Basic Improvement.

AN EXPENSIVE EXPERIMENT:

The Hydro-Electric Power Commission of Ontario. By Reginald Pelham Bolton, M. Am. Soc. C. E. Cloth, 8 x $5\frac{1}{2}$ in., illus., 281 pp. New York, The Baker & Taylor Company, 1913. $1.25. (Donated by the Author.)

The subject-matter of this volume contains, it is stated, the history of an expensive experiment in Government ownership, as developed by the investigation by the New York State Legislative Committee into the work of, and the results obtained by, the Hydro-Electric Power Commission of Ontario, the author's purpose being to place before the taxpayers of New York City the facts relative to a proposed appointment of a State Commission to regulate and control the water resources of the State for the development of electrical power for commercial purposes. The investigation has been extended by personal inquiry and analysis on the part of the author, the facts and figures given by him being stated to be official and to have been confirmed by official statements and testimony. The Contents are: The Birth of the Experiment; The Views of the Commission; Conservation of "Water Power"; Development of Hydro-Electric Energy; How the Commission Has Gone to Work; From the Public Point of View; The Application of the Experiment; The Commission's Figures; Operation of the Niagara System; The City of Ottawa; The Big Chute System; The Commission at Port Arthur; The Way Out.

HIP AND VALLEY DESIGN:

Details, Formulae, and Graphics; Roofs, Hoppers, and Pipe Lines. By H. L. McKibben and L. E. Gray. Cloth, $9\frac{1}{4}$ x $7\frac{1}{4}$ in., illus., 30 pp. Ambridge, Pa., J. E. Banks, 1912. $2.00.

The difficulty of making working shop drawings for roof connections at hip and valley being well known, this book has been prepared, it is stated, to cover the practical working details for such construction and to present the necessary analytic and graphic processes for the development of such details. The designs included herein will be found useful, it is stated, by Engineers and Architects to determine readily the style of connection adapted to their demands, by Draftsmen to save

labor, and by Students to gain the practical training in descriptive geometry and trigonometry as applied to active engineering. The authors recommend to engineering schools class-room work in the proof of the formulas.

ENGINEERING TABLES AND DATA.

By W. W. F. Pullen. Third Edition. Paper, 8½ x 5½ in., illus., 68 pp. Manchester, England, The Scientific Publishing Company. 1 shilling 6 pence.

This book contains a collection of tables and data for use in the laboratory, the testing shop, and in engineering educational work generally. The steam table, it is stated, has been entirely revised to represent the results of the latest researches, and is given in both Fahrenheit and Centigrade units. A few mathematical notes have also been added in connection with the tables. A partial list of the Contents is: Circular Measure of Angles; Natural Sines, Cosines, Tangents and Cotangents; Common Logarithms and Antilogarithms; Hyperbolic or Napierian Logarithms; Hyperbolic Functions; Measurement and Conversion Factors; Water Density Tables; Thermometer Conversion Tables, etc., etc.

DIAGRAMS FOR THE SOLUTION OF THE KUTTER AND BAZIN FORMULÆ

For the Flow of Water. Prepared by Karl R. Kennison. Paper, 11 x 8½ in., illus., unpaged. Providence, R. I., 1913. $1.00. (Donated by the Author.)

In the absence of actual discharge measurements, the formulas represented in these diagrams, it is stated, may be commonly relied on to compute the velocity of water flowing in open channels and pressure conduits. They assume a condition of uniform flow and depend, it is said, for accurate results on the right choice of a coefficient of roughness to fit the channel in question. For the proper application of the formulas, the measurement of surface slope, the determination of the coefficient of roughness, etc., reference should be had, the author states, to the many published works on Hydraulics. It is also stated that when any three of the four variables, Velocity, Slope, Hydraulic Radius, and Roughness are known, the fourth can be read off at once, in English or metric units, without using a straight edge. Examples illustrating the use of the diagrams are included.

ELEMENTS OF WESTERN WATER LAW.

By A. E. Chandler. Cloth, 9½ x 6 in., 150 pp. San Francisco, Technical Publishing Co., 1913. $2.00. (Donated by the *Journal of Electricity, Power and Gas.*)

Public interest in water resources and water rights, especially in the Western States, is so great at the present time, it is stated, that a legal treatise on the subject is excusable. The subject-matter of this book appeared first as separate articles in the *Journal of Electricity, Power and Gas,* and form part of a course on "Irrigation Institutions" for advanced students in the Colleges of Agriculture and Civil Engineering, of the University of California. Although, as stated, the text is intended for those untrained in jurisprudence, the Western law of waters having been developed by Court decisions, it has been found necessary to quote freely from such decisions, but only leading cases on each point are cited. The Chapter headings are: Early Development of the Doctrine of Appropriation; Riparian Rights in the Western States; The Law of Underground Waters; The Doctrine of Appropriation; Loss of Water Rights; Water Right Legislation; Water Rights in Interstate Streams; Rights of Way Over Public Lands for Ditches and Reservoirs; Commercial Irrigation Enterprises; The Desert Land Act and the Carey Act; The Reclamation Act; Irrigation Districts; The Desideratum in Legislation Regarding the Public Waters; Index.

THE 1913 LAKE SUPERIOR IRON ORE ANNUAL.

Compiled by The Iron Trade Review. Leather, 9¼ x 6 in., illus., 71 pp. Cleveland, Ohio, The Penton Publishing Co., 1913. $2.00.

On the title-page, it is stated that this work contains official figures on ore shipments by mines, ranges, and ports, together with complete statistics bearing on the Lake Superior ore movement since 1844, ore prices, and receipts at Lower Lake docks. There is also a short article by Edwin C. Eckel, Assoc. Am. Soc. C. E., on "Ore Mining Costs in Lake District," tables of iron content in Bessemer and non-Bessemer ores, history of ore prices, etc.

THE CONCRETE HOUSE AND ITS CONSTRUCTION.

By Maurice M. Sloan. Cloth, 9¼ x 6 in., illus., 224 pp. Philadelphia, The Association of American Portland Cement Manufacturers, 1912. $1.00.

The purpose of this book, the preface states, is to make clear the advantages of concrete as a fire-resisting, durable, sanitary, and economical material for house construction. The design of concrete houses, and all the details of construction, such as foundations, walls, floors, roofs, stairways, and chimneys, as well as methods, estimates, etc., are thoroughly discussed by the author, and numerous examples and illustrations of various types of concrete houses, doors, windows, etc., are also included.

STEEL: ITS SELECTION, ANNEALING, HARDENING AND TEMPERING.

By E. R. Markham. Fourth Edition. Cloth, 8 x 5¼ in., illus., 367 pp. New York, The Norman W. Henley Publishing Co., 1913. $2.50.

In a secondary title it is stated that this work was formerly known as "The American Steel Worker", and that it is the standard work on the hardening, tempering, and annealing of steel of all kinds, with descriptions and illustrations of methods of hardening tools and of all kinds of annealing and muffle furnaces, blast ovens, open flames, and of the uses of lead and cyanide baths, as well as case-hardening and pack-hardening. In this, the fourth edition, numerous additions regarding the most recent methods of the special-steel treatment are given, including a brief account of the more important points of annealing, hardening, tempering, and case-hardening of modern alloy steels, with data and specifications of their strengths, compositions, and properties.

THE CATSKILL WATER SUPPLY OF NEW YORK CITY:

History, Location, Sub-Surface Investigations, and Construction. By Lazarus White, Assoc. M. Am. Soc. C. E. Cloth, 9¼ x 6 in., illus., 32 + 755 pp. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Limited, 1913. $6.00.

The author's aim, it is stated, has been to present in this book, in a reliable and readable form, a contemporaneous record of the history, location, design, and construction of the work for the Catskill Water Supply. Descriptions of the modern methods of construction used by the various contractors engaged on the work, are given, including the construction of cyclopean masonry dams with block facing and expansion joints, thorough aeration of the water, building of cut-and-cover aqueduct, excavation of circular shafts, improved methods of driving and lining tunnels, etc., material for which was made available by the author's connection with the work and by the aid and co-operation of the various engineers and contractors engaged thereon. The Contents are: History of New York Water Works; The Board of Water Supply; Location of Catskill Aqueduct; Borings and Sub-Surface Investigations; Explorations for Hudson River Crossing; The Ashokan Dams and Reservoirs; Esopus Cut-and-Cover and Peak Tunnel; Rondout Pressure Tunnel and North Half Bonticou Grade Tunnel; Wallkill Pressure Tunnel, North Cut-and-Cover, and One-Half Bonticou Tunnel; Wallkill Valley Cut-and-Cover Aqueduct; Moodna, Hudson, Breakneck, and Bull Hill Tunnels of the Hudson River Division; Peekskill Division Cut-and-Cover and Grade Tunnels; Steel Pipe Lines; Croton Cut-and-Cover Aqueduct and Grade Tunnels; Grade Tunnels, Cut-and-Cover, and Pressure Aqueducts; Kensico Dam and Appurtenant Works; White Plains Division; Yonkers Pressure Tunnel and Hill View Reservoir; City Tunnel; Bronx Division; City Tunnel: Manhattan Division; Tables; Bibliography; Index.

DER BAU DER WOLKENKRATZER:

Kurze Darstelling auf Grund einer Studienreise für Ingenieure und Architekten. Von Otto Rappold. Cloth, 9½ x 6½ in., illus., 8 + 263 pp. München und Berlin, R. Oldenbourg, 1913. 12 marks.

In the Introduction the author states that in this work he has undertaken to present to the German technical world the wonders accomplished by American engineers in the construction of high buildings for hotel and business purposes. He gives detailed descriptions of the design and of the various methods and materials used in the construction of the modern "sky-scraper," from the foundation to the completed structure, as well as detail drawings and illustrations of many of the high buildings in the United States. It is further stated in the Introduction that the book offers to German engineers and architects, many interesting new methods of design and construction; to the steel worker, many new

suggestions on the construction and erection of steel skeletons; and to the concrete specialists, among many other things, a new method for heavy concreting. The Chapter headings are: Einleitung; Entstehung der Wolkenkratzer; Voraussetzung zur Ermöglichung der Wolkenkratzer; Massnahmen zur Fortleitung des Personenverkehrs während des Bauens; Fundation der Wolkenkratzer; Der Eisenaufbau; Schutz des eisernen Tragwerks gegen Witterungseinflüsse und Feuer; Deckenkonstruktionen; Scheidewände; Einrichtungen zum Hochheben der Baumaterialen für die Decken, Scheidewände, und für die Ummantelung der Eisenkonstruktion; Aussenmauern; Einrichtung innerhalb des Gebäudes zur Handhabung des Verkehrs; Maschinelle Anlagen zum Betrieb der hohen Gebäude; Wolkenkratzer aus Eisenbeton; Die Feuersicherheit der hohen Gebäude.

A TREATISE ON WOODEN TRESTLE BRIDGES

And Their Concrete Substitutes, According to the Present Practice on American Railroads. By Wolcott C. Foster. Fourth Revised and Enlarged Edition. Cloth, 12 x 9 in., illus., 19 + 440 pp. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Limited, 1913. $5.00.

The preface states that although wooden trestles are gradually disappearing from main lines of heavy traffic, the increased growth of branch lines and of trestles for electric railways and at manufacturing plants for the cheap handling and unloading of material, has kept pace with such abandonment, and it is hoped that this new edition of this work may prove useful to those engaged in their design and construction. New matter, it is stated, has been added to every chapter, and there are two new chapters, one giving a short outline of timber preservation and one on concrete trestles. Many railway clubs and engineering associations have permanent committees on wooden bridges and trestles, and the various standards and rules of practice adopted by these committees are included in the subject-matter. In Part II, the number of illustrations has been nearly doubled, it is stated, and many examples of the latest practice, especially for heavy traffic, are included. An extensive bibliography of the subject and of related matters in trestle building and maintenance is also given. The Contents are: Part I, Introduction; Pile-Bents; Pile-Drivers; Trained Bents; Floor System; Bracing, Compound-Timber Trestles, High Trestles, etc.; Iron Details; Connection with Embankment and Protection Against Accidents; Field Engineering and Erection; Preservation and Standard Specifications; Bills of Material, Records and Maintenance; Timber; Theoretical Considerations of Design; Temporary Trestles and Structures; Renewals and Replacing of Trestles; The Preservation of Trestle Timbers by Mechanical and Chemical Means; Concrete Trestles. Part II, Plates: Pile-Trestles; Framed Trestles; Electric Railroad Trestles; Miscellaneous Trestles; Ballasted Floor Trestles; Concrete Trestles. Part III, Bibliography; Index.

EXCAVATING MACHINERY.

By Allen Boyer McDaniel, M. Am. Soc. C. E. Cloth, 9½ x 6¼ in., illus., 18 + 340 pp. New York and London, McGraw-Hill Book Company, 1913. $3.00.

In the Introduction it is stated that, in recent years, the interests of designers and builders have been stimulated by the great demand for all types of excavating machinery, and that many improvements have been introduced in the present-day machine. In this book, which is intended, it is stated, for the farmer and land owner as well as for the engineer and contractor, the author has described the construction of every type of excavating machine made, the uses for which it is devised, and its application to work in various parts of the United States. Cost data are given, which have been gathered from a great variety of sources and as far as possible from operations under normal working conditions. At the end of many of the chapters, the author has included a bibliography of the subject treated. The Chapter headings are: Part I, Scrapers, Graders and Shovels: Drag and Wheel Scrapers; Road or Scraping Graders; Elevating Graders; Capstan Plow; Steam Shovel. Part II, Dredges: Dry Land Excavators; Floating Excavators; Trench Excavators; Levee Builders; The Comparative Use of Excavating Machinery. Appendix A, General Specifications for a Modern Steam Shovel for Railway Construction; Appendix B, Tests of the Mississippi River Commission for Hydraulic Dredges; Index.

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Victoria-Sludge Abatement Board. 1 pam.
Villalon, José R. 1 pam.
Virginia-Geol. Survey. 1 vol.
Virginia-State Corporation Comm. 1 bound vol.
Washington-Highway Comm. 1 map.
Washington-State Board of Health. 1 pam.
Washington-State Library. 1 pam.
Washington, Univ. of. 1 vol., 1 pam.
Waterbury, Conn.-City Engr. 1 pam.
Wellington, N. Z.-Harbour Board. 1 pam.
West Virginia-Geol. Survey. 1 map.
Western Australia-Agt.-Gen. 1 vol.
Western Australia-Geol. Survey. 2 pam.
Western Canada Irrig. Assoc. 2 pam.
Western Soc. of Engrs. 1 pam.
Whinery, Samuel. 1 pam.
Winnipeg, Man.-City Engr. 1 pam.
Wisconsin-Geol. and Natural History Survey. 1 pam.
Wisconsin-R. R. Comm. 2 bound vol.
Woburn, Mass.-Water Dept. 1 pam.
Yale Univ. 1 pam.
Ziffer, E. A. von. 1 vol.

BY PURCHASE

The New International Year Book: A Compendium of the World's Progress for the Year 1912. Edited by Frank Moore Colby. Dodd, Mead and Company, New York, 1913.

Small Water Supplies, Being a Practical Treatise on the Methods of Collecting, Storing and Conveying Water for Domestic Use in Large Country Mansions, Estates, and Small Villages and Farms, for the Use of Engineers, Estate Agents, and Owners of Country Property. By F. Noël Taylor. D. Van Nostrand Co., New York; B. T. Batsford, London.

Poor's Manual of Public Utilities: Street Railway, Gas, Electric, Water, Power, Telephone and Telegraph Companies, 1913. Poor's Railroad Manual Co., New York.

The Official Good Roads Year Book of the United States. American Highway Association, Washington, D. C., 1913.

Locomotive and Carriage Superintendents' Committee Affiliated with the Indian Railway Conference Association. Proceedings during 1912 and at the Coonoor Meeting, Dec. 2d, 1912. Alfred E. Williams, Secy., Parel, Bombay, India.

Der Schornsteinbau. Von Gustav Lang. Viertes Heft: Sockel, Grundbau, Fuchs und Einsteigoffnungen, Bekampfung der Rauch- und Russplage. Helwingsche Verlagsbuchhandlung, Hannover, 1911.

Royal Commission on Coast Erosion: First, Second and Third Reports. 3 Vol. Wyman and Sons, Limited, London; Oliver and Boyd, Edinburgh; and E. Ponsonby, Dublin, 1907–11.

The Practical Railway Spiral, with Short Working Formulas and Full Tables of Deflection Angles: Complete Notes of Illustrative Examples. By L. C. Jordan. D. Van Nostrand Co., New York, 1913.

Schubwiderstand und Verbund in Eisenbetonbalken auf Grund von Versuch und Erfahrung. Von R. Saliger. Julius Springer, Berlin, 1913.

Reports of Decisions of the Public Service Commission, First District of the State of New York; Vol. 3, Jan. 1st, 1912, to Jan. 1st, 1913. Published by the Commission, New York, 1913.

A Text-Book on Trade Waste Waters; Their Nature and Disposal. By H. Maclean Wilson and H. T. Calvert. J. B. Lippincott Co., Philadelphia; Charles Griffin & Company, Limited, London, 1913.

Modern Pumping and Hydraulic Machinery as Applied to all Purposes, with Explanation of the Theoretical Principles Involved, Construction, Working and Relative Advantages: Being a Practical Handbook for Engineers, Designers and Others. By Edward Butler. J. B. Lippincott Co., Philadelphia; Charles Griffin and Company, Limited, London, 1913.

Electrical Machine Design: The Design and Specification of Direct and Alternating Current Machinery. By Alexander Gray. McGraw-Hill Book Co., New York and London, 1913.

Liquid Steel: Its Manufacture and Cost. By David Carnegie. Assisted by Sidney C. Gladwyn. Longmans, Green and Co., New York and London, 1913.

Mitteilungen über Forschungsarbeiten auf dem Gebiete des Ingenieurwesens, insbesondere aus den Laboratorien der technischen Hochschulen. Herausgegeben von Verein Deutscher Ingenieure. Hefte 133-134. Julius Springer, Berlin, 1913.

Deutscher Ausschuss für Eisenbeton. Hefte 23-26. Wilhelm Ernst & Sohn, Berlin, 1913.

Die Wasserkräfte, ihr Ausbau und ihre wirtschaftliche Ausnutzung: Ein technisch-wirtschaftliches Lehr und Handbuch. Von Adolf Ludin. 2 Vol. Julius Springer, Berlin, 1913.

The Britannica Year-Book, 1913: A Survey of the World's Progress Since the Completion in 1910 of the Encyclopaedia Britannica, Eleventh Edition. Edited by Hugh Chisholm. The Encyclopaedia Britannica Company, New York and London, 1913.

Analytical Chemistry. By F. P. Treadwell. Authorized Translation by William T. Hall. Vol. 1, Qualitative Analysis. Third English from the Fifth German Edition. John Wiley & Sons, New York; Chapman & Hall, Ltd., London, 1913.

Cassell's Reinforced Concrete: A Complete Treatise on the Practise and Theory of Modern Construction in Concrete-Steel. Edited by Bernard E. Jones. Cassell and Company, Limited, New York, London, Toronto and Melbourne, 1913.

Steel Rails: Their History, Properties, Strength and Manufacture, with Notes on the Principles of Rolling Stock and Track Design. By William H. Sellew. D. Van Nostrand Co., New York; Constable & Co., Ltd., London, 1913.

National Association of Railway Commissioners. Proceedings of the Twenty-Fourth Annual Convention Held at Washington, D. C., November 19-22, 1912. Washington, 1913.

Report on the Necessity and Practicability of Establishing a System of Impounding Reservoirs at the Headwaters of the Alleghany, Monongahela, and Ohio Rivers and Their Tributaries. United States-Corps of Engineers. (62d Congress, 3d Session, Document No. 1289.) Government Printing Office, Washington, 1913.

Report on Survey of Ohio River, Ohio and West Virginia, with a View to the Selection of Sites for the Additional Locks and Dams Between Lock No. 8 and Lock No. 29, Including the Last-Named Lock, and for the Preparation of Plans and Estimates. United States-Corps of Engineers. (62d Congress, 3d Session, Document No. 1159.) Government Printing Office, Washington, 1913.

Tables of Cases and Opinions of the Interstate Commerce Commission: Decisions, under Act of 1906, from August, 1906, to June, 1912, Vols. XII to XXIII, Inclusive. Government Printing Office, Washington, 1912.

The Biographical Directory of the Railway Officials of America, 1913 Edition. Edited and Compiled by Harold Francis Lane. McGraw-Hill Book Co., New York and London.

Thermodynamik der Turbomaschinen: Thermodynamische Bewertung und Berechnung der Dampfsturbinen, Turbo-Kompressoren, Turbo-Kältemaschinen und Gasturbinen unter besonderer Berücksichtigung graphischer Verfahren. Von Guido Zerkowitz. R. Oldenbourg, München und Berlin, 1913.

Computations for Marine Engines. By C. H. Peabody. John Wiley & Sons, New York; Chapman & Hall, Limited, London, 1913.

Refractories and Furnaces: Properties, Preparation, and Application of Materials Used in the Construction and Operation of Furnaces. By F. T. Havard. McGraw-Hill Book Company, New York and London, 1912.

Handbuch der Ingenieurwissenschaften: Dritter Teil. Der Wasserbau: Stauwerke. Von P. Gerhardt, K. E. Hilgard, E. Mattern, und Th. Rhebock. Zweiter Band, Vierte, vermehrte Auflage. Wilhelm Engelmann, Leipzig, 1910.

SUMMARY OF ACCESSIONS

(From May 5th to July 31st, 1913)

Donations (including 63 duplicates)	892
By purchase	38
Total	930

MEMBERSHIP

ADDITIONS

(From May 9th to August 7th, 1913)

MEMBERS		Date of Membership.
ALLPORT, JAMES HOBART. Cons. Engr. and Pres., Clinchfield Coal Corporation, Barnesboro, Pa.		July 2, 1913
AMBURN, WILLIAM WESLEY. Engr. in Chg., Great Falls & Teton County Ry. in Montana, 265 East 86th St., Portland, Ore.	Assoc. M. M.	Sept. 2, 1908 June 4, 1913
BARNARD, WILFRED KEEFER. 515 North Vega St., Alhambra, Cal.	Assoc. M. M.	Nov. 8, 1909 July 2, 1913
BARTON, WALTER CHEW. Junior Engr., U. S. Engr. Dept., Metropolitan Bank Bldg., New Orleans, La.	Assoc. M. M.	July 1, 1908 April 2, 1913
BAYLES, GEORGE HARMON. Engr. in Chg. of Constr., Stony River Dam, Dobbin, W. Va.		June 4, 1913
BEER, PAUL. Mgr., Barber Asphalt Paving Co., Des Moines, Iowa	Assoc. M. M.	Oct. 4, 1905 July 2, 1913
BLACK, GURDON GILMORE. Engr. in Chg., Supply and Purifying Div., St. Louis Water Dept., 34 East Grand Ave., St. Louis, Mo.	Assoc. M. M.	Oct. 5, 1909 July 2, 1913
BOATRITE, JAMES EDWIN. Gen. Mgr., Guerber Eng. Co., Bethlehem, Pa.	Jun. Assoc. M. M.	Feb. 5, 1895 Nov. 3, 1897 May 7, 1913
BOWERMAN, HORATIO BEVAN. Chf. Const. Engr., Bureau of Lighthouses, 15 West 29th St., Baltimore, Md.		June 4, 1913
CHENEY, SHERWOOD ALFRED. Maj., Corps of Engrs., U. S. A.; Secy., California Débris Comm., 405 Custom House, San Francisco, Cal.		July 2, 1913
CLARK, WAYNE ALMON. Chf. Engr., The Duluth & Iron Range R. R., 510 Wolvin Bldg., Duluth, Minn.		July 2, 1913
CLEMENT, SHELDON BYRNE. Chf. Engr. and Supt. of Maintenance, Temiskaming & North. Ont. Ry., North Bay, Ont., Canada		May 7, 1913
COLBY, ELMER ELLSWORTH. Chf. Engr., St. L., Oklahoma & Pacific R. R., Chickasha, Okla.		Jan. 7, 1913
COLE, EDWARD SMITH. Hydr. Engr.; Mgr. and Cons. Engr., The Pitometer Co., 220 Broadway, New York City	Assoc. M. M.	Sept. 7, 1904 June 4, 1913
CONRAD, LOWELL EDWIN. Prof. of Civ. Eng., State Agricultural Coll., 317 North 17th St., Manhattan, Kans.	Assoc. M. M.	Oct. 3, 1906 July 2, 1913
CRUISE, EDGAR DUDLEY. Asst. Engr., Ore. Short Line R. R., Ashton, Idaho		June 4, 1913

MEMBERS (*Continued*)

Member	Grade	Date of Membership.
CULYER, THURSTON CARLYLE. Asst. Engr., Dept. of Water Supply, Gas and Electricity, New York City, Purdy Station, N. Y.		June 4, 1913
DOTEN, LEONARD SMITH. Civ. Engr., War Dept. (Res., 410 A St., N. E.), Washington, D. C.	Assoc. M. M.	July 9, 1913 June 4, 1913
DRANE, BRENT SKINNER. 1205 Commercial Bank Bldg., Charlotte, N. C.	Assoc. M. M.	July 10, 1907 May 7, 1913
DUDER, JOHN. Prin. Asst. City Engr., 125 M. St., Salt Lake City, Utah	Assoc. M. M.	Nov. 8, 1909 June 4, 1913
DURHAM, LEICESTER. Asst. Engr., Board of Water Supply, City of New York, Box 26, New Paltz, N. Y.		May 7, 1913
FROMMER, CHARLES. Asst. Engr., Sewer Design, Bureau of Surveys, 2610 North 29th St., Philadelphia, Pa.		June 4, 1913
GALES, ROBERT RICHARD. Engr. in Chf., Lower Ganges Bridge, Paksey, Bengal, India		Mar. 4, 1913
GRAVELL, WILLIAM HENRY. (Franklin & Co.), 1420 Chestnut St., Philadelphia, Pa.	Assoc. M. M.	April 4, 1911 July 2, 1913
HALL, LOUIS WELLS. 1302 Wancoma St., Birmingham, Ala.	Assoc. M. M.	Oct. 1, 1902 July 2, 1913
HARRISON, CHRISTOPHER. City Engr., City Hall, Everett, Mass.		May 7, 1913
HAYS, JOHN COFFEE. Cons. Elec. Engr., Visalia, Cal.	Assoc. M.	May 4, 1909 June 4, 1913
HESS, EDWIN WESLEY. Kratzer Bldg., Clearfield, Pa.		May 7, 1913
HOWARD, RALPH HILLS. Gen. Mgr., New Orleans Great North. R. R., Jackson, Miss.		July 2, 1913
HOWIE, HOWARD BENSON WILBERFORCE. Chf. Engr., West Constr. Co., Chattanooga, Tenn.	Jun. Assoc. M. M.	Mar. 6, 1906 Dec. 6, 1910 June 4, 1913
HOWLAND, LEWIS ABNER. Gen. Supt., Queens Borough Gas & Elec. Co., Far Rockaway, N. Y.		July 2, 1913
HURD, HURD CLARENCE. Care, Riegos y Fuerza del Ebro, S. A., Tremp, Lerida, Spain		July 2, 1913
INSLEY, WILLIAM HENRY. Pres. and Gen. Mgr., Insley Mfg. Co., Indianapolis, Ind.	Assoc. M. M.	Aug. 31, 1909 June 4, 1913
JENKINS, CHARLES EDWIN. Engr. of Ways, Easton Transit Co., 431 Clinton St., Easton, Pa.		May 7, 1913
JOHNSON, GEORGE ARTHUR. Hydr. and San. Engr. (Johnson & Fuller), 150 Nassau St., New York City	Assoc. M. M.	Feb. 6, 1907 July 2, 1913
JONES, OWEN MERIWETHER. Asst. Engr., Michigan Lake Superior Power Co., 306 Barbean St., Sault Ste. Marie, Mich.		April 2, 1913

MEMBERS (*Continued*)

Name and Address	Grade	Date of Membership.
KELLER, WILLIAM SIMPSON. State Highway Engr., Capitol, Montgomery, Ala.		July 2, 1913
LATHROP, JAY COWDEN. Civ. and Mech. Engr., Northern Ohio Power Co., 220 Hamilton Bldg., Akron, Ohio	Assoc. M. M.	Oct. 2, 1907 Feb. 4, 1913
LEAHY, MAURICE JOSEPH. South Hadley Falls, Mass.	Assoc. M. M.	Dec. 4, 1907 June 4, 1913
LEWIS, EDWARD ROWLAND. Asst. to Gen. Mgr., Duluth, South Shore & Atlantic Ry., 904 Fidelity Bldg., Duluth, Minn.		May 7, 1913
MCCAUSLAND, CHARLES PATTERSON. Locating Engr., The West. Md. Ry., P. O. Box 465, Hagerstown, Md.	Assoc. M. M.	Dec. 6, 1910 July 2, 1913
MCRAE, JOHN BELL. Cons. Engr., Citizen Bldg., Ottawa, Ont., Canada		May 7, 1913
MILLER, WASHINGTON J. Archt. and Structural Engr., 45 Kearny St., San Francisco, Cal.		Jan. 7, 1913
MILLS, GEORGE CLARK. 402 Livingston Bldg., Rochester, N. Y.		June 4, 1913
MITCHAM, GEORGE NATHAN. City Engr., Opelika and Auburn; State Highway Commr.; Prof. of Civ. Eng., Alabama Polytechnic Inst., Auburn, Ala.	Assoc. M. M.	Nov. 8, 1909 June 4, 1913
MONSARRAT, CHARLES NICHOLAS. Chairman and Chf. Engr., Board of Engrs., Quebec Bridge, 709 New Birks Bldg., Montreal, Que., Canada		Mar. 4, 1913
NORCROSS, PAUL HOWES. Civ., Structural and Hydr. Engr. (Solomon-Norcross Co.), 1622 Candler Bldg., Atlanta, Ga.	Assoc. M. M.	July 9, 1906 May 7, 1913
PAGET, JOHN PORTMAN. Engr. and Contr. (Paget & Birkett), Casilla 733, Guayaquil, Ecuador		April 2, 1913
PARKER, DORSEY JULIAN. Gen. Supt. and Chf. Engr., Am. Coal Corporation, 1312 Glen Iris Ave., Birmingham, Ala.		July 2, 1913
PEARSE, LANGDON. Div. Engr., in Chg., Sewage Disposal, San. Dist. of Chicago, Karpen Bldg., Chicago, Ill.	Jun. Assoc. M. M.	Jan. 6, 1903 Oct. 7, 1908 July 2, 1913
PHILLIPS, HOWARD CRATHORNE. Valuation Engr., A., T. & S. F. System, 1033 Ry. Exchange, Chicago, Ill.	Jun. Assoc. M. M.	April 5, 1892 Sept. 6, 1899 June 4, 1913
PHILLIPS, JASPER MARION. Scott City, Kans.		July 2, 1913
PRACK, BERNARD HERMAN. Archt. and Engr. (Prack & Perrine), 36 James St., South, Hamilton, Ont., Canada		May 7, 1913
REAL Y GAILLARD, JUAN D. Chf. Engr., Dept. of Public Works, Province of Oriente, Santiago de Cuba, Cuba.		June 4, 1913

MEMBERS (*Continued*)		Date of Membership.
REDFIELD, CHARLES MONTIETH. Chf. Engr., Central Oregon Irrig. Co., Deschutes, Ore		June 4, 1913
REINKE, FREDERICK JARRETT. Asst. Chf. Engr., St. L., Troy & East. R. R. and St. L., Columbia & Waterloo Ry., 726 Bayard Ave., St. Louis, Mo		July 2, 1913
SALMON, JOHN MCCLURE. Asst. Bridge Engr., L. & N. R. R., 4638 South First St., Louisville, Ky		June 4, 1913
SCHLUMPF, OSCAR LEONARD. Chf. Draftsman and Asst. Engr., Chester & Fleming, Union Bank Bldg., Pittsburgh (Res., 625 Broad St., Sewickley), Pa		May 7, 1913
SCHNEIDER, ANTON. Supt., Amalgamated Phosphate Co., Brewster, Fla	Assoc. M. M.	May 4, 1898 July 2, 1913
SEABURY, GEORGE TILLEY. Asst. Engr., Board of Water Supply, 13 Lake St., White Plains, N. Y	Jun. Assoc. M. M.	Mar. 31, 1903 Dec. 1, 1908 May 7, 1913
SIMPSON, JOHN THOMAS. Cons. Engr. and Archt., 1224 Essex Bldg., Newark, N. J		July 2, 1913
SOLOMON, GABRIEL ROBERTS. Civ., Structural and Hydr. Engr. (Solomon-Norcross Co.), 1622 Candler Bldg., Atlanta, Ga	Assoc. M. M.	Oct. 2, 1907 May 7, 1913
STEGNER, CLIFFORD MILTON. Archt. and Engr. (Stegner, Hughes & Alves), 1014 Commercial Tribune Bldg., Cincinnati, Ohio.	Assoc. M. M.	May 2, 1911 July 2, 1913
STRUCKMANN, HOLGER. Chf. Engr. and Gen. Mgr., Iola Portland Cement Co., 815 Commerce Bldg. (Res., 1618 Linwood Boulevard), Kansas City, Mo	Assoc. M.	Nov. 20, 1909 May 7, 1913
SULLIVAN, MURRAY. Office Engr., Ore. Short Line R. R., 606 Deseret News Bldg., Salt Lake City, Utah	Assoc. M. M.	Sept. 6, 1910 May 7, 1913
TIDD, ARTHUR WARREN. Senior Section Engr., New York City Board of Water Supply, Hill View Div., Yonkers (Res., 10 Oakwood Ave., White Plains), N. Y	Assoc. M. M.	June 3, 1903 May 7, 1913
TILDEN, CHARLES JOSEPH. Prof. and Head of Dept. of Eng. Mechanics, Univ. of Michigan, 1619 Cambridge Rd., Ann Arbor, Mich.	Jun. Assoc. M. M.	May 31, 1898 Feb. 5, 1902 June 4, 1913
TILT, GARRET EDWARD. Chf. Engr., Structural Dept., John Monks & Sons, 82 Beaver St., New York City	Assoc. M. M.	June 1, 1909 May 7, 1913
TURNEAURE, FREDERICK EUGENE. Cons. Engr.; Dean, Coll. of Mechanics and Eng., Univ. of Wisconsin, Madison, Wis	Assoc. Assoc. M. M.	Aug. 31, 1897 June 4, 1902 July 2, 1913
VOSHELL, JAMES THEODORE. Senior Highway Engr., Office of Public Rds., Washington, D. C		July 2, 1913

MEMBERS (*Continued*)

		Date of Membership.
WALLER, OSMAR LYSANDER. Prof. of Math. and Civ. Eng., State Coll. of Washington, Pullman, Wash.		July 2, 1913
WALLS, JOHN ABBET. Cons. Engr., Shawinigan Water & Power Co. and Chf. Engr., Pennsylvania Water & Power Co. at Holtwood, Pa.; Room 39, U. S. Fidelity & Guaranty Bldg., Baltimore, Md.		June 4, 1913
WARREN, PHILIP RIDSDALE. Chf. Engr., Norton Griffiths & Co., Ltd., 308 Dominion Express Bldg., Montreal, Que., Canada		July 2, 1913
WATSON, WILLIAM CRAVEN. Bridge Designer, N. Y., N. H. & H. R. R., 45 Smith St., West Haven, Conn.		May 7, 1913
WEAKLAND, FRANCIS LEE. Asst. Chf. Engr., Bolivia Central Ry., Casilla 106, La Paz, Bolivia		Mar. 4, 1913
WELLS, GEORGE HENRY. 11 East 24th St., New York City.		May 7, 1913
WHEELER, WALTER SCOTT. Prin. Asst. Engr. to Chf. of Irrig., Peruvian Govt., Apartado 889, Lima, Peru.		Dec. 3, 1912
WIGGINS, WILLIAM D. Valuation Engr., Penn. Lines W. of Pitts., Pennsylvania Station, Pittsburgh, Pa.	Assoc. M. M.	Oct. 2, 1901 July 2, 1913
WILD, HERBERT JOSEPH. Prof. of Eng., Pennsylvania Military Coll., Chester, Pa.	Jun. Assoc. M. M.	Mar. 31, 1903 April 6, 1904 June 4, 1913
WILLIAMS, CYRIL, JR. Civ. and Hydr. Engr., 1015 Scott St., San Francisco, Cal.		June 4, 1913

ASSOCIATE MEMBERS

AGNEW, AUGUSTUS WATEROUS. (Ritchie, Agnew & Co.), Agnew Blk., Prince Rupert, B. C., Canada		July 2, 1913
ALBERT, DANIEL WESLEY. Care, Great Western Power Co., Keddie, Cal.		June 4, 1913
AUTEN, CLAUDE ISAAC. Res. Engr., Bates Mfg. Co., Lewiston, Me.	Jun. Assoc. M.	Sept. 1, 1908 June 4, 1913
BAGBY, FRANCIS CYRUS. Mgr., St. Louis Dist. Office, Corrugated Bar Co. of Buffalo, N. Y., 1409 National Bank of Commerce Bldg., St. Louis, Mo.		July 2, 1913
BAILEY, ALBERT ROSS. Instr. in Ry. Eng. and Surveying, Univ. of Michigan, 914 Lincoln Ave., Ann Arbor, Mich.		July 2, 1913
BENNETT, WILLIAM BRYANT. Civ. and Public Service Engr., 422 West Wilson St., Madison, Wis.		May 7, 1913
BERNSTEIN, LESTER. Asst. Superv. of Station Service, B. & O. R. R., Care, Third Vice-Pres., B. & O. R. R., Baltimore, Md.	Jun. Assoc. M.	Feb. 28, 1905 May 7, 1913
BLACK, CLARENCE NEELLY. Chf. Engr., Gulf Pipe Line Co. and J. M. Guffy Petroleum Co., 1418 North St., Beaumont, Tex.		June 4, 1913

ASSOCIATE MEMBERS (*Continued*)

Member		Date of Membership.
BLACK, JOHN CECIL. 4011 North 35th St., Tacoma, Wash.		July 2, 1913
BLACK, ROBERT ALEXANDER. Div. Engr., Transcontinental Ry., Quebec, Que., Canada		July 2, 1913
BLAIR, ALEXANDER. City Engr., Summit, N. J.		May 7, 1913
BOARDMAN, WILLIAM HARRIS. 71 Mapes Ave., Newark, N. J.		June 4, 1913
BOYAJOHN, HAIG MILTON. Cons. Engr. and Contr. (Boyajohn-Arnold Co.), 907 Wilcox Bldg., Portland, Ore.		June 4, 1913
BRASLOW, BARNETT. Engr., Bureau of Municipal Research, 2975 Valentine Ave., New York City		June 4, 1913
BRENNAN, JAMES GREGORY. Asst. Engr., State Comm. of Highways, 251 Western Ave., Albany, N. Y.		June 4, 1913
BRIGHT, DUDLEY SEYMOUR. 812 Diamond Bank Bldg., Pittsburgh, Pa.		April 2, 1913
BRITTON, GEORGE CHESTER. Supt. for Barrally & Ingersoll, Hemlock, N. Y.		Feb. 4, 1913
BROOKING, JOSEPH HUGH. Asst. Engr., Office of Chf. Engr. of Operation, St. L. & S. F. R. R., Frisco Bldg., Springfield, Mo.		May 7, 1913
BROOKS, CLARENCE MORRISON. Div. Engr., State Highway Dept., P. O. Box 260, Keene, N. H.		July 2, 1913
BROWN, ELMER HOVEY. Hempstead, N. Y.		Dec. 3, 1912
BROWN, JOHN MAUGHS. In Chg., Dept. of Civ. Eng., Univ. of South Dakota, 103 North Univ. St., Vermilion, S. Dak.		June 4, 1913
BUNDY, OSCAR HAROLD. Chf. Engr., Washington & Old Dominion Ry., 1517 H St., N. W., Washington, D. C.		July 2, 1913
BURR, MYRON CARLOS. Civ., Hydr. and Min. Engr., Fort George, B. C., Canada	Jun. Assoc. M.	May 4, 1909 Jan. 7, 1913
CAHILL, JOHN RICHARD. Structural Engr. and Contr., 460 Montgomery St., San Francisco, Cal.	Jun. Assoc. M.	April 30, 1907 June 4, 1913
CHRISTIAN, CHARLES STEPHEN. Engr., Morgan Eng. Co., Texarkana, Ark.		Jan. 7, 1913
COHEN, ABRAHAM BURTON. Asst. Engr. in Chg. of Concrete Constr., D., L. & W. R. R., Room 315, U. S. Express Bldg., Hoboken, N. J.		July 2, 1913
COOKSEY, ROBERT MAVIN. Prin. Asst. Engr., Paving Comm., 207 City Hall, Baltimore, Md.		July 2, 1913
CULVER, ARTHUR. Oficina del Subterraneo, Estacion Once, Ferro Carril Oeste de Buenos Aires, Ltd., Buenos Aires, Argentine Republic		May 7, 1913
CUNNINGHAM, PINKNEY EDWARD. Insp., U. S. War Dept., P. O. Box 421, Vicksburg, Miss.	Jun. Assoc. M.	July 1, 1909 June 4, 1913
CUTTING, ROBERT CURTIS. Junior Engr., Engr. Dept., U. S. A., Hogsett, W. Va.		April 2, 1913

ASSOCIATE MEMBERS (*Continued*)		Date of Membership.
DAUDT, RALPH BRUÈRE. Chf. Engr., A. Bentley & Sons Co., Toledo, Ohio		May 7, 1913
DAVIDSON, THOMAS MEREDITH. Asst. Western Mgr., Concrete Steel Co., 1106 Monadnock Bldg., Chicago, Ill.		Jan. 7, 1913
DAVIS, PHILIP CHAPIN. 858 Howard Ave., Bridgeport, Conn.		June 4, 1913
DELÉRY, EUGENE FRANK. Draftsman, Sewerage and Water Board of New Orleans, 2007 Laharpe St., New Orleans, La		May 7, 1913
DOOLITTLE, FREDERICK WILLIAM. Asst. Prof. of Mechanics, Coll. of Eng., Univ. of Wisconsin; With R. R. Comm. of Wisconsin, 939 University Ave., Madison, Wis	Jun. Assoc. M.	April 5, 1910 July 2, 1913
DOYEN, GEORGE EVELYN. 1950 Bogart Ave., New York City.		July 2, 1913
DRAGER, WALTER LOUIS. Asst. City Engr., 34 Elm St., Schenectady, N. Y	Jun. Assoc. M.	May 3, 1910 May 7, 1913
DUNHAM, FRED CALVIN. 1514 West Providence Ave., Spokane, Wash		May 7, 1913
EARLE, WARREN CLIFFORD. Chf. Engr., Railroad Comm. of the State of California, 833 Market St., San Francisco, Cal		Feb. 4, 1913
EDY, JOHN NORTH. Asst. City Engr., Box 881, Billings, Mont	Jun. Assoc. M.	Oct. 31, 1911 April 2, 1913
EPPS, FREDERICK WILLIAM. 934 Armstrong Ave., Kansas City, Kans		May 7, 1913
FERGUSON, JOHN ASHLEY. Engr., Bureau of Bldg. Inspection, Dept. of Public Safety, Public Safety Bldg., Pittsburgh, Pa		May 7, 1913
FLICK, JOHN KRAMER. Res. Engr., Baltimore City Water Dept., Loch Raven, Md	Jun. Assoc. M.	Jan. 31, 1911 July 2, 1913
FÖLLING, BJARNE NICOLAS. Chf. Engr., Southern States Steel Co., 1411 Praetorian Bldg., Dallas, Tex		July 2, 1913
FOWLER, CHARLES WORTHINGTON. With Snare & Triest, Engr. on Constr., Pier 5, P. O. Box 1197, San Juan, Porto Rico		July 2, 1913
FOWLER, FRANK HOYT. 4755 Eleventh Ave., N. E., Seattle, Wash.		May 7, 1913
FROST, HARRY HENRY. Gen. Supt. and Engr., City Water-Works, 584 East Buchtel Ave., Akron, Ohio		June 4, 1913
GAILOR, CHESTER FRANCIS. Roadmaster, The Connecticut Co., Drawer 31, Hartford, Conn		June 4, 1913
GALLAGHER, JOSEPH. Myers, N. Y		Jan. 7, 1913
GARVIN, EDGERTON CHESTER. Junior Engr., U. S. Engr. Dept., Savannah, Ga	Jun. Assoc. M.	Dec. 3, 1907 June 4, 1913

ASSOCIATE MEMBERS (*Continued*)		Date of Membership.
GOULD, CHESTER MASON. Section Engr., Board of Water Supply, City of New York, Cold Spring, N. Y.	Jun. Assoc. M.	April 6, 1909 June 4, 1913
GRAVES, GEORGE AUGUSTUS. Member of Firm, Trenton Eng. Co., Room 210, Commonwealth Bldg., Trenton, N. J.		June 4, 1913
HALSEY, MILO CLINTON. Structural Engr., M. of W. Dept., Pacific Elec. Ry., 239 North Canyon Boulevard, Monrovia, Cal.	Jun. Assoc. M.	June 30, 1910 June 4, 1913
HANDLEY, HARVEY LOCKHART. Chf. Engr., New Mexico-Colorado Coal & Min. Co., Yankee, N. Mex.		July 2, 1913
HANIQUE, JULES EDMOND. 2271 East 19th St., Oakland, Cal.		June 4, 1913
HARDING, SIDNEY TWICHELL. Irrig. Engr., Office of Experiment Stations, U. S. Dept. of Agri., 3216 Third Ave., North, Billings, Mont.	Jun. Assoc. M.	Sept. 5, 1905 May 7, 1913
HARLAN, CLARENCE HALLER. Structural Engr., McClintic-Marshall Constr. Co., 426 Sample St., Millvale, Pa.		June 4, 1913
HAYNE, DANIEL CARLOS. Constr. Engr. and Supt., Cleary-Kuert Co., Inc., 802 Hume-Mansur Bldg., Indianapolis, Ind.		May 7, 1913
HEIDEL, BENJAMIN FRANKLIN. Senior Highway Engr., Office of Public Rds., U. S. Dept. of Agri., 605 Iroquois Apartments, Washington, D. C.		June 4, 1913
HENDRIE, JOHN GIBSON. Engr. and Supt. of Constr., The New Trinidad Lake Asphalt Co., Ltd., Brighton, Trinidad.	Jun. Assoc. M.	Sept. 5, 1911 April 2, 1913
HESS, JOHN STRIDER. Designing Engr., Duryea, Haehl & Gilman, 1318 Humboldt Bank Bldg., San Francisco, Cal.	Jun. Assoc. M.	Oct. 5, 1909 July 2, 1913
HOLLOWAY, ROGER TIFFT. 50 Church St., New York City.	Jun. Assoc. M.	May 31, 1910 May 7, 1913
HOWARD, JOEL MANNING. First Asst. Engr., State Highway Dept., Cleveland Bldg., Watertown, N. Y.		June 4, 1913
HOWE, CLARENCE DECATUR. Chf. Engr., Grain Comm. of Canada, Fort William, Ont., Canada.	Jun. Assoc. M.	Oct. 5, 1909 May 7, 1913
HOWES, DONALD WINTHROP. Supt., Carpenter & Boxley & Herrick, 375 Ovington Ave., Brooklyn, N. Y.	Jun. Assoc. M.	April 4, 1905 July 2, 1913
HOYT, WILLIAM GLENN. Dist. Engr., Water Resources Branch, U. S. Geological Survey, Old Capitol Bldg., St. Paul, Minn.		July 2, 1913

ASSOCIATE MEMBERS (*Continued*)		Date of Membership.
HUGHES, WILLIAM RICHARD, JR. 812 Coal St., Wilkinsburg, Pa.	Jun. / Assoc. M.	June 1, 1909 / May 7, 1913
JACOBS, JACOB LOUIS. Engr. in Chg., Efficiency Div., Chicago Civ. Service Comm., 5651 Drexel Ave., Chicago, Ill.		June 4, 1913
JAMES, EDWIN WARLEY. U. S. Chf. Insp. of Public Rds., 7205 Blair Rd., Washington, D. C.		July 2, 1913
JENNINGS, PERCY JOHN. Inspecting Engr., Dominion Govt., Irrig. Branch, Dept. of the Interior, P. O. Drawer V, Calgary, Alberta, Canada		June 4, 1913
JOHNSON, DAVID CLAYTON. Asst. Engr. to H. de B. Parsons, Cons. Engr., 22 William St., New York City (Res., 245 Hewes St., Brooklyn, N. Y.)	Jun. / Assoc. M.	Sept. 1, 1908 / May 7, 1913
JOHNSTON, THOMAS STEWART. Chf. Engr., The L. E. Myers Co., 1117 Monadnock Bldg., Chicago, Ill.		May 7, 1913
JONES, LEE MORGAN. City Engr., Port Arthur, Ont., Canada		July 2, 1913
KELLOGG, FRANCES WILLIAM. Stony River Dam, Dobbin, W. Va.		May 7, 1913
KLEIN, ROY ALTON. Garden Home, Ore.		June 4, 1913
KOHL, ERNEST WILLIAM, JR. Chf. Engr., The Spanish Am. Iron Co., Santiago de Cuba, Cuba		July 2, 1913
KROMER, CLARENCE HERBERT. Asst. Structural Engr., California State Dept. of Eng., Sacramento, Cal.		May 7, 1913
LARSEN, HENRY. Engr., Doyle, Patterson & Beach, 401 Worcester Bldg., Portland, Ore.		April 2, 1913
LEE, ERNEST EUGENE. Supt., Erection of Machinery and Elec. Equipment, Isthmian Canal Comm., Culebra, Canal Zone, Panama		Mar. 4, 1913
LYMAN, JAMES DUNCAN KNAPP. Asst. Engr., The Mt. Vernon Bridge Co., 508 East Chestnut St., Mt. Vernon, Ohio		June 4, 1913
LYNCH, ALEXANDER SYDNEY. 57 Holmes St., West Haven, Conn.	Jun. / Assoc. M.	Dec. 6, 1910 / June 4, 1913
McCLELLAND, CARL ARMOR. Hydrographer, Twin Falls Land & Water Co., Milner, Idaho		July 2, 1913
McRAE, HENRY CLINTON. Div. Engr., Baltimore Sewerage Comm., Colgate, Md.		May 7, 1913
MAHONE, WILLIAM, JR. Asst. Res. Engr., Norfolk & South. R. R., Norwood, N. C.	Jun. / Assoc. M.	April 5, 1910 / July 2, 1913
MARCH, GEORGE MILES. Chf. Engr., Brett Eng. & Contr. Co., Wilson, N. C.		May 7, 1913
MERRICK, HORACE GUY. U. S. Junior Engr., La Crosse, Wis.		May 7, 1913

ASSOCIATE MEMBERS (*Continued*)		Date of Membership.
MOORE, WALTER SMYTH. Engr., M. of W., L. & A. R. R., Versailles, Ky...........	Jun.	Dec. 6, 1910
	Assoc. M.	July 2, 1913
MOOREFIELD, CHARLES HENRY. Highway Engr., Office of Public Rds., U. S. Dept. of Agri., Washington, D. C.		May 7, 1913
MORRIS, EDWIN THADDEUS ALBINUS. 2183 Broadway, New York City		June 4, 1913
MURPHY, JAMES JOSEPH. Civ. Engr. to Commr. of Parks and Boulevards, 199 Cherry St., Detroit, Mich.....		July 2, 1913
NIMMO, WILLIAM HOGARTH ROBERTSON. Care, F. Fricke, Esq., Victorian Govt. Representative, 687 Market St., San Francisco, Cal.........................		April 2, 1913
PALMER, WALLACE CROMWELL ALLEN. Asst. Engr. in Chg. of Constr., Gas Mains, in City of Manila, Dept. of Eng. and Public Works, Manila, Philippine Islands..		May 7, 1913
PATTERSON, CHARLES LAWSON. Asst. Engr., Arkansas Val. Ditch Assoc., 421 Broadway, Pueblo, Colo..........		July 2, 1913
PHILLIPS, RICHARD EDWARD. Engr., Barge Canal Office, Lyon Bldg., Albany, N. Y........................		May 7, 1913
POMMERER, ROBERT WILLIAM. With Board of Water Supply, City of New York, 343 West 29th St., New York City.		July 2, 1913
PRATT, CAREY SIMON. City Civ. Engr., Urbana, Ohio......		June 4, 1913
REID, CECIL LATTA. Res. Engr., in Chg. of Constr., Fredericksburg Power Co., P. O. Box 144, Fredericksburg, Va.		July 2, 1913
RHODES, GLENN VERNON. Asst. Engr., South San Joaquin Irrig. Dist., Manteca, Cal.	Jun.	May 3, 1910
	Assoc. M.	May 7, 1913
RISLEY, WARNER IRELAN. City Engr., Somers Point and Ventnor City, 648 Bartlett Bldg., Atlantic City, N. J.		June 4, 1913
ROBINSON, HARRY. Engr. and Supt., Atlantic Constr. & Supply Co., 135 St. James Pl., Atlantic City, N. J..		May 7, 1913
ROSS, ROBERT JOHN. Asst. Engr., Dept. of Eng. of Hartford, 84 Whitmore St., Hartford, Conn............		May 7, 1913
RUSSELL, VERNEY WARREN. Asst. Engr., U. S. Reclamation Service, Cody, Wyo............................		July 2, 1913
SCHOBINGER, GEORGE. Asst. Engr., U. S. Reclamation Service, Yuma, Ariz......	Jun.	Oct. 5, 1909
	Assoc. M.	July 2, 1913
SHANK, LYMAN CHAMBERS. Asst. Gen. Mgr. and Chf. Engr., The International Steel Tie Co., Hippodrome Bldg. (Res., 8219 Brookline Ave., N. E.), Cleveland, Ohio.		June 4, 1913
SHAW, PERCY AUGUSTUS. 511 Hand Ave., Lancaster, Pa..		May 7, 1913
SMITH, HERBERT JAMES. Prin. Asst. Engr., East Haddam Bridge Comm., East Haddam, Conn...............		June 4, 1913
SMITH, JONATHAN RHODES. Ch'f. Draftsman, The Jobson Gifford Co., 30 East 42d St., New York City..................	Assoc.	Dec. 5, 1911
	Assoc. M.	May 7, 1913

ASSOCIATE MEMBERS (*Continued*)		Date of Membership.
SOVEREIGN, HARRY EVANS. 1066 President St., Brooklyn, N. Y.		April 2, 1913
SPERRY, LOUIS NEWTON. Tupper Lake, N. Y.		May 7, 1913
STEVENSON, JOHN DICKSON. Asst. Engr., Div. of Bridges, Bureau of Constr., Dept. of Public Works, 1231 Monterey St., N. S., Pittsburgh, Pa.		July 2, 1913
STILSON, JAY ALVORD. Street Engr., City Engr.'s Office, 355 Willis Ave., West, Detroit, Mich.		May 7, 1913
STONE, GEORGE BURRILL. 518 Vermont Bldg., Salt Lake City, Utah		May 7, 1913
STOTT, SAMUEL EDWIN. Structural Engr., Swift & Co., 34 North Market St., Boston, Mass.		May 7, 1913
STRINGFELLOW, HARRIS MARTYN. Civ. Engr., Mexico Tramways Co. and Mexican Light & Power Co., Apartado 124 Bis, City of Mexico, Mexico		Mar. 4, 1913
SWARTZ, FREDERICK PETER. Dist. Engr., St. L. & S. F. R. R., 536 South St., Springfield, Mo.		May 7, 1913
SYMONDS, GEORGE ROSCOE BLAINE. Asst. Engr., Bureau of Public Works, Manila, Philippine Islands		Mar. 4, 1913
TAYLOR, NELSON. 624 South Burlington Ave., Los Angeles, Cal.	Jun. Assoc. M.	Sept. 5, 1911 July 2, 1913
TULLOCK, HUBERT SOUTHWICK. Asst. Secy. and Treas., in Chg. of Highway Dept., The Mo. Val. Bridge & Iron Co., Leavenworth, Kans.		June 4, 1913
VANDERVOORT, BENJAMIN FRANKLIN. Altmar, N. Y.	Jun. Assoc. M.	Mar. 2, 1909 July 2, 1913
VAN HOOK, FRANKLIN JAMES. Asst. Engr., Dept. of Public Service, 304 Odd Fellows Temple, Cincinnati, Ohio.		May 7, 1913
VON GELDERN, EDWARD. Engr. of Reclamation Dist. No. 777 of Sutter County, Yuba City, Cal.	Jun. Assoc. M.	May 5, 1908 July 2, 1913
WADDELL, NEEDHAM EVERETT. Res. Engr., Waddell & Harrington, 1012 Baltimore Ave., Kansas City, Mo.	Jun. Assoc. M.	Sept. 1, 1908 May 7, 1913
WARDLAW, JAMES THOMPSON. In Chg. of Constr. Dept., Lockwood, Greene & Co., 616 Rhodes Bldg., Atlanta, Ga.		June 4, 1913
WEBB, WILLIAM TIBBITTS. Engr. for Quartermaster, U. S. Military Academy, West Point, 44 LeRoy Pl., Newburgh, N. Y.		May 7, 1913
WEIR, WALTER WALLACE. Drainage Engr., Office of Experiment Stations, U. S. Dept. of Agri., 310 Federal Bldg., North Yakima, Wash.		May 7, 1913
WEISS, HERMAN OTTO. Asst. Engr., Atlantic Coast Line Appraisal, Lock Box 183, Wilmington, N. C.		July 2, 1913

ASSOCIATE MEMBERS (*Continued*)		Date of Membership.
WELLS, HERBERT CASSIDY. Supt. of Rd. Constr., U. S. Dept. of Agri., Office of Public Rds., Washington, D. C.		Mar. 4, 1913
WHITE, ROBERT CULIN. Asst. Engr., Mo. Pac. R. R., Room 209, Union Depot, Little Rock, Ark		June 4, 1913
WILLARD, WILLIAM CLYDE. Asst. Engr., Panama-Pacific International Exposition, San Francisco (Res., 5680 Ocean View Drive, Oakland), Cal	Jun. Assoc. M.	Feb. 4, 1908 June 4, 1913
WOODS, HARLAND CLARK. Asst. Prof. of Civ. Eng., Robert Coll., Constantinople, Turkey	Jun. Assoc. M.	Feb. 28, 1911 May 7, 1913
WYSE, FREDERICK CALHOUN. Engr. and Supt. of Sewerage and Water Depts., Columbia, S. C		July 2, 1913
YOST, HOWARD MCCLYMONDS. Chf. Engr., Dept. of Public Service, City Hall, Massillon, Ohio	Jun. Assoc. M.	June 6, 1911 May 7, 1913
YOUNG, CHARLES ASA DILTS. U. S. Engr. Office, Seattle, Wash		Jan. 7, 1913

ASSOCIATES

DOUTY, DANIEL ELLIS. Gen. Mgr., U. S. Conditioning & Testing Co., 340 Hudson St., New York City		May 7, 1913
FINCH, STANLEY PHISTER. Instr. in Civ. Eng., Univ. of Texas, Austin, Tex	Jun. Assoc.	Oct. 30, 1906 May 7, 1913
ROCKWOOD, NATHAN CHAMBERLAIN. Asst. Editor, *Engineering News*, 505 Pearl St., New York City (Res., 255 Marlborough Rd., Brooklyn, N. Y)		July 2, 1913
RUSSELL, ALEXANDER ALLEN MACVICAR. 2712 Stuart St., Berkeley, Cal	Jun. Assoc.	May 5, 1908 Feb. 4, 1913

JUNIORS

ALLAN, WILLIAM SELBY. 648 Cornelia Ave., Chicago, Ill.	June 4, 1913
BRUSH, CHARLES BENJAMIN. 113 West 69th St., New York City	June 4, 1913
GEBHARDT, JOHAN FRIEDRICH WILHELM. Asst. to Economic Engr., Stone & Webster Eng. Corporation, P. O. Box 293, Keokuk, Iowa	Feb. 4, 1913
GRAY, RALPH MOSES. 1418 Thirteenth St., Sacramento, Cal	July 2, 1913
GRISWOLD, HAROLD WILEY. Care, Eng. Dept., Board of Water Commrs., Pilgard Bldg., Hartford, Conn	May 7, 1913
HAMILTON, PETER DAVIDSON GUNN. Needham, Mass	Feb. 4, 1913
HASWELL, JOHN ROBERT. Drainage Engr., Office of Experiment Stations, U. S. Dept. of Agri., Box A, Easton, Md	June 4, 1913
HAYDOCK, CHARLES. 922 Arcade Bldg., Philadelphia, Pa.	June 4, 1913

JUNIORS (*Continued*)	Date of Membership.
HEIDEL, CHARLES SUMNER. Hydrographer, State Engr.'s Office, Helena, Mont	July 2, 1913
HUIE, IRVING VAN ARNAM. Senior Draftsman and Asst. Engr., F. A. Molitor, 223 East 31st St., New York City	May 7, 1913
JOHNSON, ARCADIUS LARS PETER. Asst. Designer, Carrère & Hastings, 211 East 35th St., New York City	June 4, 1913
KRACH, FRED ROY. With U. S. Engr. Office, Rock Island, Ill	July 2, 1913
LAMB, SYDNEY BISHOP. 2652 Lafayette St., Denver, Colo.	Jan. 7, 1913
LICHTENSTEIN, HARRY. Asst. Engr., Board of Water Supply, City of New York, 1102 Washington Ave., New York City	May 7, 1913
MAGOR, STUART FABIAN. 1715 Hope St., South Pasadena, Cal	Jan. 7, 1913
MICHENER, HOWARD PERRY. 451 George St. New Haven, Conn	May 7, 1913
MONROE, ROBERT ANSLEY. 245 Buchanan St., San Francisco, Cal	April 2, 1913
OSTROM, CHARLES DOUGLAS YELVERTON. Asst. Insp., Board of State Harbor Commrs., 2949 Steiner St., San Francisco, Cal	July 2, 1913
PORTER, HOWARD SAMUEL. Chf. Engr., State Highway Dept., State Capitol, Hartford, Conn	May 7, 1913
RAKESTRAW, CHARLES LYSANDER. Chf. of Party No. 2, Div. 4, California Highway Comm., Berkeley, Cal	June 4, 1913
REDLIEN, WILLIAM HENRY. 23 Lexington Ave., Richmond Hill, N. Y	May 7, 1913
REILLY, CHARLES GILBERT. With Pittsburgh Rys. Co., Castle Shannon Div., 5th Ave. and Darragh St., Pittsburgh, Pa	May 7, 1913
ROSE, ALSTON ORANGE. Asst. Engr., Hawaii Loan Fund Comm., Kamuela, Hawaii	July 2, 1913
ROSE, JOSEPH. With Gustav Lindenthal, Cons. Engr., 68 William St., New York City	July 2, 1913
ROSSIG, EDGAR WILLIAM. 69 Hauxhurst Ave., Weehawken, N. J	May 7, 1913
ROWE, DONALD HEFLEY. With Waddell & Harrington, 380 East 14th St., North, Portland, Ore	May 7, 1913
SANDELANDS, EDWARD BURCHARD. Insp., U. S. Engr. Dept., Quintana, Tex	May 7, 1913
TRUESDELL, ARCHIE MERLE. Brilliant, B. C., Canada	June 4, 1913
VAN ETTEN, PERCY HIXON. Asst. Res. Engr., South San Joaquin Irrig. Dist., Box 125, Manteca, Cal	Feb. 4, 1913

JUNIORS (*Continued*) Date of Membership.

WARING, FREDERICK HOLMAN. With Metcalf & Eddy, 14 Beacon St., Boston, Mass	May 7, 1913
WARKLEY, JOHN CROSWELL. 777 Adams St., Gary, Ind	Dec. 3, 1912

CHANGES OF ADDRESS

MEMBERS

ABBOT, FREDERIC VAUGHAN. Col., Corps of Engrs., U. S. A., Army Bldg., New York City.

ADAM, ROBERT. 40 Gayton Rd., Harrow, Middlesex, England.

ALDEN, HERBERT CLARENDON. Asst. Engr., Bureau of Sewers, Borough of the Bronx, Municipal Bldg., 177th St. and Third Ave., New York City.

ANDERSEN, CHRISTIAN. 466 Tenth St., Portland, Ore.

ARMSTRONG, WALTER ROOT. Asst. Gen. Mgr., Salt Lake & Utah R. R., Room 704, Newhouse Bldg., Salt Lake City, Utah.

ARNOLD, WILLIAM HARRY. 470 West 22d St., New York City.

ARTHUR, HOWARD ELMER. Big Hollow, N. Y.

ASSERSON, HENRY RAYMOND. With Civil Service Comm., 495 Sixth St., Brooklyn, N. Y.

BALDWIN, THOMAS WILLIAMS. 41 Hawthorne St., Cambridge, Mass.

BARNES, THOMAS HOWARD. Civ. and Municipal Engr., United Fruit Co., Puerto Barrios, Guatemala.

BARNES, WILLIAM THOMAS. Member of Firm, Metcalf & Eddy, 1824 Harris Trust Bldg., Chicago, Ill.

BECKWITH, FRANK. Engr.-in-Chf., Am. Section of the Hu Knang Rys., Ichang, China.

BEEMAN, THOMAS RUPE. Dist. Engr., C., M. & St. P. Ry., 617 White Bldg., Seattle, Wash.

BINKLEY, GEORGE HOLLAND. Mesa, Ariz.

BISHOP, HUBERT KEENEY. Chf. Engr., Waiahole Water Co., Ltd., Hackfeld Bldg., Honolulu, Hawaii.

BOGEN, LOUIS EDWARD. Chf. Elec. Estimating Engr., The Allis-Chalmers Co. (Res., 3324 State St.), Milwaukee, Wis.

BRADLEY, DANIEL EDWARD. 1021 Asylum Ave., Hartford, Conn.

BREITHAUPT, WILLIAM HENRY. Cons. Engr., 243 Confederation Life Bldg., Toronto, Ont., Canada.

BROWN, PERRY FISHER. Key Route Inn, Oakland, Cal.

BROWNE, WILLIAM LYON. 1380 Greene Ave., Westmount, Que., Canada.

BROWNELL, ERNEST HENRY. Civ. Engr., U. S. N., Naval Station, Key West, Fla.

BURROWES, HARRY GILBERT. Cons. Engr., Care, Engineers' Club, 32 West 40th St., New York City.

CAMPEN, GEORGE LINDEN. Cons. Engr., 858 Omaha National Bank Bldg., Omaha, Nebr.

CARR, WALTER FRANK. Care, Ry. Dept., Parrott & Co., 320 California St., San Francisco, Cal

MEMBERS (*Continued*)

CLARK, ERNEST ALDEN. 106 North La Salle St., Room 10 Chicago, Ill.

CLEMENT, FRANK HUDSON. Engr. and Contr., Land Title Bldg., Philadelphia, Pa. (Res., Hempstead, N. Y.)

COLLINS, RODERICK GREENE, JR. Contr. Engr., 1108 Woodward Bldg., Washington, D. C.

COMSTOCK, CHARLES WORTHINGTON. 514 First National Bank Bldg., Denver, Colo.

CORNISH, LORENZO DANA. 15 West 108th St., New York City.

CUMMINGS, ROBERT AUGUSTUS. Cons. Engr., 1607 Machesney Bldg., Pittsburgh, Pa.

CUNNINGHAM, ANDREW CHASE. Civ. Engr., U. S. N.; Insp. of Public Works, Navy Yard, Portsmouth, N. H.

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CUSHMAN, WILLIAM HERBERT. Box 134, Scotia, N. Y.

DAVIS, CHARLES HENRY. South Yarmouth, Mass.

DENNIS, WILLIAM FRANKLIN. Cons. Engr.; Vice-Pres., Rinehart & Dennis Co., 2201 Massachusetts Ave., N. W., Washington, D. C.

DOTY, JOHN WILLIAMS. With The Foundation Co., Ltd., Bank of Ottawa Bldg., Montreal, Que., Canada.

DRURY, EDMUND HAZEN. Sherbrooke, Que., Canada.

ELLIOTT, CHARLES GLEASON. Cons. Drainage Engr., 503 McLachlen Bldg., Washington, D. C.

ELLIS, GEORGE EZRA. 302 East 43d St., Kansas City, Mo.

FARLEY, GODFREY PEARSON. Care, L. I. R. R., Jamaica Terminal Station, Room 502 (Res., The Franklin, Hardenbrook Ave.), Jamaica, N. Y.

FELT, CHARLES FREDERICK WILSON. Chf. Engr., A., T. & S. F. Ry. System, Ry. Exchange Bldg., Chicago, Ill.

FENKELL, GEORGE HARRISON. Commr. of Public Works (Res., 297 Seyburn Ave.), Detroit, Mich.

FISHER, FRANCIS DAVIS. 60 Wall St., Room 2207, New York City.

FLAD, EDWARD. Cons. and Const. Engr. (Edward Flad & Co.), De Menil Bldg., St. Louis, Mo.

GOODWIN, JAMES BOWMAN. Supt. of Constr., Midland Constr. Co., 6 Algonquin Ave., Toronto, Ont., Canada.

GOULD, WILLIAM TILLOTSON. R. F. D. No. 5, Easton, Pa.

GRAY, JOHN HENRY. Vice-Pres., Roanoke Bridge Co., Inc., Roanoke, Va.

GREEN, HUBERT EDWARD. Chf. Engr., Compania Constructora Richardson, S. A., 1030 I. N. Van Nuys Bldg., Los Angeles, Cal.

GREENE, ROBERT MAXSON. Structural Engr., Peabody, Kans.

GREGORY, LUTHER ELWOOD. Civ. Engr., U. S. N., U. S. Navy Yard, Puget Sound, Bremerton, Wash.

GUTMAN, DAVID. Chf. Engr. with John G. Brown, Witherspoon Bldg., Philadelphia, Pa.

HAINES, HENRY STEVENS. Care, Crivelli & Co., Lucerne, Switzerland.

MEMBERS (*Continued*)

HAMMER, JOHANNES MARCELIUS. Care, Frank Kneeland Machine Co., 54th St. and Allegheny Val. R. R., Pittsburgh, Pa.

HAWXHURST, ROBERT, JR. Cons. Engr., Care, International Bank, 60 Wall St., New York City.

HAYDEN, JOHN BRUCE. 430 Texas St., San Francisco, Cal.

HEALY, JOHN FRANCIS. Cons. Min. Engr., Room 1201, Union Bldg., Charleston, W. Va.

HILL, CURTIS. City Engr., 44 East Concord Ave., Kansas City, Mo.

HOGUE, CHESTER JAMES. 618 Oregonian Bldg., Portland, Ore.

HOHL, LEONHARD JOHN. Cons. Engr., Room 601, Underwood Bldg., San Francisco, Cal.

HOLMAN, MINARD LAFEVER. Cons. Eng. (Holman & Laird), 1324 Chemical Bldg., St. Louis, Mo.

HOTCHKISS, LOUIS JENISON. 4144 Kenmore Ave., Chicago, Ill.

HOUSTON, GAVIN NELSON. Irrig. Office, Dept. of The Interior, Calgary, Alberta, Canada.

HOXIE, RICHARD LEVERIDGE. Brig.-Gen., U. S. A. (*Retired*), Iowa City, Iowa.

HUNT, WILLIAM HENRY. Cons. Engr., 2 Rector St., Room 1922, New York City.

JANES, FREDERICK SPENCER. Care, Abitibi Pulp & Paper Co., Ltd., Iroquois Falls, Ont., Canada.

JAQUES, WILLIAM HENRY. Counselling Engr.; Pres., Hampton Water-Works Co., Little Boar's Head, N. H.

KAFKA, FREDERICK PERCIVAL. Pres. and Mgr., The Fireproof Products Co., Inc., 257 East 133d St., New York City (Res., 49 Washington Ave., New Rochelle, N. Y.).

KIBBE, AUGUSTUS SAYRE. Cons. Engr., 2385 Oregon St., Berkeley, Cal.

KIMBALL, JOSEPH HARRIS. Cons. Civ., Hydr., and San. Engr., 414 Louisville Trust Bldg., Louisville, Ky.

KING, PAUL SOURIN. 1012 Washington St., Wilmington, Del.

KLUEGEL, CHARLES HENRY. 1507 Alexander St., Honolulu, Hawaii.

KONDO, SENTARO. 27 Tatsuokacho, Hongo, Tokyo, Japan.

LEBARON, JOHN FRANCIS. Cons. Engr., Conomo Point, Essex, Mass.

LEIGHTON, MARSHALL ORA. Cons. Engr., 502 McLachlin Bldg. (Res., 4200 Sixteenth St., N. W.), Washington, D. C.

LELAND, WARREN ALLSTON. Pres., Tennessee Eastern Elec. Co., Johnson City, Tenn.

LIPSEY, THOMAS EUGENE LEARD. 15 West 108th St., New York City.

LOREE, LEONOR FRESNEL. Pres., Delaware & Hudson Co.; Chairman of Board and Executive Committee, Kansas City South. Ry., 32 Nassau St., New York City (Res., Bowood, West Orange, N. J.).

MCCARTHY, GEORGE ARNOLD. 219 Prince Arthur St., West, Montreal, Que., Canada.

MCKIM, JAMES ARTHUR. (Wilcox-McKim Co.), Saginaw, Mich.

MEMBERS (*Continued*)

McNulty, George Washington. Care, Engrs.' Club, 32 West 40th St., New York City.

McReynolds, Orval Omar. Pres., Board of Public Utilities, 218 City Hall Annex, Los Angeles, Cal.

Marshall, Robert Albertsen. Structural Engr., Westinghouse, Church, Kerr & Co., 37 Wall St., Room 910, New York City.

Mathewson, Thomas Knight. Apartado 1839, City of Mexico, D. F., Mexico.

Means, Thomas Herbert. Agri. Engr. (Symmes, Means & Chandler), 419 Holbrook Bldg., San Francisco, Cal.

Merrill, Oscar Charles. Chf. Engr., U. S. Dept. of Agri., Forest Service, Atlantic Bldg., Washington, D. C.

Miner, Edward Fuller. Pres., Edward F. Miner Bldg. Co., 25 Foster St., Worcester, Mass.

Morris, Marshall. Cons. Engr., 10 Waukesha National Bank Bldg., Waukesha, Wis.

Morse, Charles Adelbert. Chf. Engr., Rock Island Lines, 803 La Salle St. Station, Chicago, Ill.

Morse, Walter Levi. Chf. Engr., Jacksonville Terminal Co., Jacksonville, Fla.

Murray, Ray Messinger. Care, Montana Bridge & Structural Co., Stapleton Blk., Billings, Mont.

Newbrough, William. Care, Penberthy Injector Co., Detroit, Mich.

O'Brien, Joseph Henry. With Westinghouse, Church, Kerr & Co., 901 Shaughnessy Bldg., Montreal, Que., Canada.

Ornellas, Charles Evariste d'. Care, J. G. White & Co., Ltd., 9 Cloak Lane, London, E. C., England.

Paret, Milnor Peck. Asst. Engr., Utah Ry., 755 East 2d South, Salt Lake City, Utah.

Phillips, Alfred Edward. Prof., Civ. Eng., Armour Inst. of Technology, 1240 Morse Ave., Chicago, Ill.

Pond, Henry Otis. Mech. Engr., Westinghouse, Church, Kerr & Co., 37 Wall St., New York City.

Porter, Sam Graham. Inspection Engr., Staff of Commr. of Irrig., Dept. of Interior, Calgary, Alberta, Canada.

Post, George Browne. 101 Park Ave., New York City.

Price, William Gunn. 710 South 6th St., North Yakima, Wash.

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KELLERSBERGER, ARNOLD CHARLES. Wharton, Tex.

KHACHADOORIAN, HAROOTUN HOVHANNES. Res. Engr., N. T. Ry., St. Elenthere, Que., Canada.

KIENLE, JOHN ASPIN. San. Engr., Electro Bleaching Gas Co., 25 Madison Ave., New York City.

L'AMOUREAUX, HAROLD DANE. Care, C. P. R. R. Survey, Puslinch, Ont., Canada.

LEE, CHESTER SHERMAN. 1123 Woodycrest Ave., New York City.

LETTON, HARRY PIKE. San. Engr., U. S. Public Health Service, 1315 Clifton St., N. W., Washington, D. C.

LEWIS, CHESTER BROOKS. Supt., William E. Rust, Conover Bldg., Dayton, Ohio.

MCCLURE, HUNTER. Y. M. C. A., Richmond, Va.

MANZANILLA Y CARBONELL, JOSÉ JUSTO. Asst. Engr., T. L. Huston Contr. Co., Habana 88, Havana, Cuba.

MORRISON, WILLIAM HARRISON, JR. 288 Hawthorne Ave., Ludlow, N. Y.

PACKARD, JOHN CUNNINGHAM. P. O. Box 747, Wheeling, W. Va.

PARSONS, MAURICE GIESY. 910 South Madison Ave., Pasadena, Cal.

PARTRIDGE, JOHN FREDERICK. Brown's Valley, Cal.

PAUL, THEODORE LOCHART. 14 Pleasant St., Dorchester, Mass.

PERRIN, LESTER WILLIAM. Care, Chf. Engr.'s Office, C. P. Ry., Montreal, Que., Canada.

PHALAN, JOHN JOSEPH FRANCIS. 211 Paul Bldg., Utica, N. Y.

PICKFORD, EDMUND JOHN. Asst. Constr. Engr., Wade & Dorman, Ltd., P. O. Box 4242, Johannesburg, Transvaal, South Africa.

PLUMP, ERICH MOORE. Care, Missouri State Capitol Comm., Jefferson City, Mo.

RASMUSSEN, ALVIN CHRISTIAN. Asst. Engr., Insley Mfg. Co., 2209 Central Ave., Indianapolis, Ind.

JUNIORS (*Continued*)

REGESTER, HENRY SLICER, JR. Asst. Engr., Sewerage Comm., 606 Phœnix Bldg., Baltimore, Md.

RICHARDS, ARTHUR. 773 State St., Schenectady, N. Y.

SACKETT, ARTHUR JOHNSON. Engr., Mason & Hanger Co., Van Cortlandt Park, New York City.

SCHEDLER, CARL WILLIAM, JR. Care, The Foundation Co., Ltd., Box 215, Ottawa, Ont., Canada.

SCUDDER, CHARLES MORRISON. Care, Knoxville Power Co., Alcoa, Tenn.

SEE, RUSSELL ALVA. New Florence, Mo.

SELTZER, HYMEN AARON. With Am. Bridge Co., 5133 Cates Ave., St. Louis, Mo.

SERRA, JULIUS HERSCHEL. 539 East 4th St., Brooklyn, N. Y.

SHAW, WALTER FARNSBY. Care, Dept. of State Engr. and Surv., Barneveld, N. Y.

SHEA, CHELIUS HAZEL. Care, Morgan Eng. Co., City National Bank Bldg., Dayton, Ohio.

SHIELDS, JAMES RALPH. Asst. in Testing Laboratory, Univ. of California, 1830 Francisco St., Berkeley, Cal.

SMITH, ROBERT HALL, JR. Asst. Roadmaster, N. & W. Ry., Pulaski, Va.

SMITH, ROY ELMER. 954 North Main St., Pocatello, Idaho.

SMITH, SHALER GORDON. Care, Rockford Gas Light & Coke Co., Gas Works, Avon St., Rockford, Ill.

SNYDER, HUBERT EARL. Engr. of Constr., Logan Min. Co., Logan, W. Va.

SOO-HOO, PETER. Asst. Engr., Kwong Yueh-Han Ry., in Chg., Section No. 16, Care, Yueh-Han Ry., Canton, China.

STARR, WILLIAM H. Care, "Under the Maples", Pottersville, N. Y.

STEARNS, FRED LEROY. 173 Hicks St., Brooklyn, N. Y.

STIEVE, WILLIAM MATTHEW. 41 Phelps St., Lyons, N. Y.

STOREY, FRANK BURNS. Junior Engr., U. S. Geological Survey, 406 Federal Bldg., Tacoma, Wash.

STRAIN, BENJAMIN. Wallaceton, Va.

STRANDBERG, GEORGE ROBERT. 1736 West 63d St., Seattle, Wash.

TATUM, ROBERT LEE. U. S. Junior Engr., Lock and Dam No. 3, Riverton, La.

THACKWELL, HENRY LAWRENCE. Asst. Engr., The Gray Donald Gen. Eng. Co., Ltd., 409 Belmont House, Victoria, B. C., Canada.

THOMPSON, JAMES ARTHUR. Transitman, I. R. T. Co., 50 Park Pl., New York City.

TIMBERLAKE, SETH MARTIN. 74 First Pl., Brooklyn, N. Y.

TUFTS, WILLIAM. Care, Walsh's Holyoke Steam Boiler Works, Holyoke, Mass.

TYLER, RICHARD GAINES. Care, City Engr.'s Office, Austin, Tex.

VANNEMAN, ARTHUR VOSBURY. Care, Tyrone Gas & Water Co., Tyrone, Pa.

VEATCH, NATHAN THOMAS, JR. Care, Worley & Black, 301 Reliance Bldg., Kansas City, Mo.

JUNIORS (*Continued*)

WACHTEL, LOUIS. Asst. Engr., State Highway Comm., White Lake Corners, N. Y.

WINTON, WALTER FERRELL. Lieut., First U. S. Field Artillery, Camp Stotsenburg, Pampanga, Philippine Islands.

ZABRISKIE, AARON J. 116 Nassau St., New York City (Res., 245 Whiton St., Jersey City, N. J.).

RESIGNATION

JUNIOR	Date of Resignation.
MAYNARD, HENRY WARNER	May 7, 1913

DEATHS

BOGART, SAMUEL STOCKTON. Elected Associate, April 7th, 1886; died May 29th, 1913.

BONZANO, ADOLPHUS. Elected Member, August 7th, 1872; died May 5th, 1913.

COOPER, SAMUEL LISPENARD. Elected Member, February 6th, 1889; died May 8th, 1913.

DANFORTH, FREDERIC. Elected Member, September 2d, 1891; died June 6th, 1913.

FRANCIS, GEORGE BLINN. Elected Junior, September 5th, 1883; Member, November 7th, 1888; died June 9th, 1913.

HARRIS, HENRY ALEXANDER. Elected Junior, October 31st, 1899; Associate Member, June 7th, 1905; died January 9th, 1913.

HAUGH, JAMES CHARLES. Elected Member, February 2d, 1909; died July 6th, 1913.

HERRICK, HORACE THEOPHILUS. Elected Member, October 29th, 1912; died May 26th, 1913.

JANVRIN, NED HERBERT. Elected Junior, October 5th, 1897; Associate Member, June 5th, 1901; Member, April 4th, 1911; died July 17th, 1913.

MOSMAN, ALONZO TYLER. Elected Member, July 1st, 1885; died June 9th, 1913.

RADENHURST, WILLIAM NAPIER. Elected Junior, July 7th, 1875; Member, July 7th, 1880; date of death unknown.

RAYMOND, CHARLES WALKER. Elected Member, June 1st, 1892; died May 3d, 1913.

SAYLES, ROBERT WILSON. Elected Associate Member, April 5th, 1905; Member, May 5th, 1908; date of death unknown.

TISDALE, CHARLES HARRY. Elected Associate Member, October 31st, 1911; died April 30th, 1913.

Total Membership of the Society, August 7th, 1913, 7 074.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST

(May 5th to July 30th, 1913)

NOTE.—*This list is published for the purpose of placing before the members of this Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS

In the subjoined list of articles, references are given by the number prefixed to each journal in this list:

(1) *Journal*, Assoc. Eng. Soc., Boston, Mass., 30c.
(2) *Proceedings*, Engrs. Club of Phila., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Chicago, Ill., 50c.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Gesundheits Ingenieur*, München, Germany.
(8) *Stevens Institute Indicator*, Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *Engineering Record*, New York City, 10c.
(15) *Railway Age Gazette*, New York City, 15c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Electric Railway Journal*, New York City, 10c.
(18) *Railway and Engineering Review*, Chicago, Ill., 15c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 20c.
(21) *Railway Engineer*, London, England, 1s. 2d.
(22) *Iron and Coal Trades Review*, London, England, 6d.
(23) *Railway Gazette*, London, England, 6d.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *Railway Age Gazette, Mechanical Edition*, New York City, 20c.
(26) *Electrical Review*, London, England, 4d.
(27) *Electrical World*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal*, Royal Society of Arts, London, England, 6d.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium, 4 fr.
(31) *Annales* de l'Assoc. des Ing. Sortis des Ecoles Spéciales de Gand, Brussels, Belgium, 4 fr.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France, 1 fr.
(34) *Portefeuille Economiques des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(36) *Cornell Civil Engineer*, Ithaca, N. Y.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(39) *Technisches Gemeindeblatt*, Berlin Germany, 0, 70m.
(40) *Zentralblatt der Bauverwaltung*, Berlin, Germany, 60 pfg.
(41) *Elektrotechnische Zeitschrift*, Berlin, Germany.
(42) *Proceedings*, Am. Inst. Elec. Engrs., New York City, $1.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governors Island, New York Harbor, 50c.
(45) *Colliery Engineer*, Scranton, Pa., 25c.
(46) *Scientific American*, New York City, 15c.
(47) *Mechanical Engineer*, Manchester, England, 3d.
(48) *Zeitschrift*, Verein Deutscher Ingenieure, Berlin, Germany, 1, 60m.
(49) *Zeitschrift für Bauwesen*, Berlin, Germany.
(50) *Stahl und Eisen*, Düsseldorf, Germany.
(51) *Deutsche Bauzeitung*, Berlin, Germany.
(52) *Rigasche Industrie-Zeitung*, Riga, Russia, 25 kop.
(53) *Zeitschrift*, Oesterreichischer Ingenieur und Architekten Verein, Vienna, Austria, 70h
(54) *Transactions*, Am. Soc. C. E., New York City, $12.

(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $6.
(57) *Colliery Guardian*, London, England, 5d.
(58) *Proceedings*, Engrs.' Soc. W. Pa., 803 Fulton Bldg., Pittsburgh, Pa., 50c.
(59) *Proceedings*, American Water-Works Assoc., Troy, N. Y.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *Industrial World*, 59 Ninth St., Pittsburgh, Pa., 10c.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 5c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 6d.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England, 6d.
(69) *Der Eisenbau*, Leipzig, Germany.
(71) *Journal*, Iron and Steel Inst., London, England.
(71*a*) *Carnegie Scholarship Memoirs*, Iron and Steel Inst., London, England.
(72) *American Machinist*, New York City, 15c.
(73) *Electrician*, London, England, 18c.
(74) *Transactions*, Inst. of Min. and Metal., London, England.
(75) *Proceedings*, Inst. of Mech. Engrs., London, England.
(76) *Brick*, Chicago, Ill., 10c.
(77) *Journal*, Inst. Elec. Engrs., London, England, 5s.
(78) *Beton und Eisen*, Vienna, Austria, 1, 50m.
(79) *Forscherarbeiten*, Vienna, Austria.
(80) *Tonindustrie Zeitung*, Berlin, Germany.
(81) *Zeitschrift für Architektur und Ingenieurwesen*, Wiesbaden, Germany.
(82) *Mining and Engineering World*, Chicago, Ill., 10c.
(83) *Gas Age*, New York City, 15c.
(84) *Le Ciment*, Paris, France.
(85) *Proceedings*, Am. Ry. Eng. Assoc., Chicago, Ill.
(86) *Engineering-Contracting*, Chicago, Ill., 10c.
(87) *Railway Engineering and Maintenance of Way*, Chicago, Ill., 10c.
(88) *Bulletin* of the International Ry. Congress Assoc., Brussels, Belgium.
(89) *Proceedings*, Am. Soc. for Testing Materials, Philadelphia, Pa., $5.
(90) *Transactions*, Inst. of Naval Archts., London, England.
(91) *Transactions*, Soc. Naval Archts. and Marine Engrs., New York City.
(92) *Bulletin*, Soc. d'Encouragement pour l'Industrie Nationale, Paris, France.
(93) *Revue de Métallurgie*, Paris, France, 4 fr. 50.
(94) *The Boiler Maker*, New York City, 10c.
(95) *International Marine Engineering*, New York City, 20c.
(96) *Canadian Engineer*, Toronto, Ont., Canada, 10c.
(98) *Journal*, Engrs. Soc. Pa., Harrisburg, Pa., 30c.
(99) *Proceedings*, Am. Soc. of Municipal Improvements, New York City, $2.
(100) *Professional Memoirs*, Corps of Engrs., U. S. A., Washington, D. C., 50c.
(101) *Metal Worker*, New York City, 10c.
(102) *Organ für die Fortschritte des Eisenbahnwesens*, Wiesbaden, Germany.
(103) *Mining and Scientific Press*, San Francisco, Cal., 10c.
(104) *The Surveyor and Municipal and County Engineer*, London, England, 6d.
(105) *Metallurgical and Chemical Engineering*, New York City, 25c.
(106) *Transactions*, Inst. of Min. Engrs., London, England, 6s.
(107) *Schweizerische Bauzeitung*, Zürich, Switzerland.
(108) *Southern Machinery*, Atlanta, Ga., 10c.

LIST OF ARTICLES

Bridges.

Points in the Design of Arches in Ferro-Concrete.* R. N. Stroyer, M. Copenhagen Inst. of Engrs. (11) Apr. 25.
Why Some Bridges Fail.* (60) May.
Design of an Arch System by the Method of the Ellipse of Elasticity.* A. C. Janni. (41) May.
A Comparative Study of Limiting Span, Maximum Span, and Economic Span for Suspension Bridges and Cantilever Bridges.* D. B. Steinman. (Paper read before the Congress of Eng. and Scientific Societies.) (86) May 7; (14) May 17.
Tests of Grouting Gravel in River Beds. H. H. Cartwright. (13) May 8.
Erecting the St. Lawrence River Bridge.* (15) May 9.
Ferro-Concrete Bridge Over the River Lagan.* (12) May 9.
Erecting the Boucanne River Viaduct. (14) May 10.

*Illustrated.

Bridges—(Continued).

New Type of Rail Joint for Bascule and Vertical Lift Bridges.* (18) May 10; (86) May 28.
The City Waterway Bridge, Tacoma, Washington.* (13) May 15.
Girder Bridges in India. (23) May 16.
Reinforced Concrete Bridge at Rome.* (12) May 16.
Atherton Avenue Highway Bridge, Pittsburgh.* (14) May 17.
Replacing Sumner Street Bridge, Toledo.* (14) May 17.
Test-Loading Until Breaking Point of a 100-Foot Arch Bridge.* V. J. Elmont. (96) May 22.
Some Construction Features of the Substructure of the Cumberland River Bridge, L. & N. Ry.* Howard M. Jones. (13) May 22.
Replacing Lower Chord of a Drawspan While in Service.* (14) May 24.
Colorado Street Bridge Over Arroyo Seco, Concrete Arch Structure with Curved Alignment at Pasadena, Cal.* E. E. Howard. (14) May 24; (13) July 24.
Method of Replacing a Five-Span Through Truss Bridge with Deck Plate Girder Spans, Chicago & Alton Railway.* (86) May 28.
The Yardley Bridge Across the Delaware River, Philadelphia & Reading Ry.* (13) May 29.
The Layout of a Small River Crossing.* C. D. Norton. (96) May 29.
Moving the Union Pacific Kaw River Bridge.* (14) May 31.
The Largest Reinforced Concrete Bridge in America: A Viaduct with a Clear Span of Over 300 Feet.* Frank C. Perkins. (19) May 31.
Concrete Bridge for a Rural Community.* (14) May 31.
Reinforced Concrete Piles on the Chicago, Rock Island and Pacific Railway.* (14) May 31.
A Small Bascule Highway Draw Span.* L. E. Moore. (Paper read before the Boston Soc. of Civ. Engrs.) (1) June.
Overhead Highway Arch of Artistic Design.* A. M. Wolf. (87) June.
Traversing Bridges. Henry Grattan Tyrrell. (86) June 4.
Concrete Culverts.* F. H. McKechnie. (96) Serial beginning June 5.
Direct-Lift Drawbridges Without Cables.* (13) June 5.
A Vertical-Lift Drawbridge Without Cables.* (13) June 5.
St. Lawrence Bridge Company's New Shop.* (14) June 7.
General Method for Drawing Influence Lines for Stress in Simple Trusses.* Malverd A. Howe. (13) June 12.
A Wooden Trestle Bridge Carried on Timber Beams.* (13) June 12.
Waterman Avenue Culvert, Over River des Pères, St. Louis, Mo.* Charles W. Martin. (13) June 12.
Erecting a Plate-Girder Bridge with a Gantry Traveler.* (14) June 14.
Renewing Two Swing Spans Under Traffic.* (15) June 20.
Some of the More Recent Municipal Works of Rochdale.* S. S. Platt. (Paper read before the Institution of Min. and County Engrs.) (104) June 20.
Plate Girder Bridges in Railway Construction.* C. H. Marrs. (96) Serial beginning June 26.
Foundation Work on the Pitt River Bridge.* (14) June 28; (96) June 19.
Bush and Gunpowder River Bridges.* (87) July.
A Plate Girder Railroad Bridge Protected with Concrete.* (67) July.
Lift Bridges of Milwaukee.* Henry G. Tyrrell. (60) July.
A Comparison of the Different Types of Wearing Surfaces Used for the Roadways of Bridges. Henry B. Drowne. (Paper read before the Third Inter. Road Congress.) (86) July 9.
Skeleton Abutment of Reinforced Concrete for a Street Bridge at South Lorain, Ohio.* T. L. Gibson. (86) July 9.
A Four-Span Reinforced Concrete Deck Plate Girder Bridge, Typifying Illinois Highway Commission Practice.* (86) July 9.
Emergency Bridge Reconstruction: Baltimore & Ohio R. R.* (13) July 10.
Sydney Harbour Bridge.* (104) July 11.
Novel Bridge Repair Job.* Edward Stingel. (14) July 12.
A Double-Deck Bascule Bridge.* (13) July 17.
New Highway Bridge at Lytton, B. C.* (96) July 17.
Bridges, Viaducts and Embankment Work of the New York Connecting Railroad.* (14) July 19.
Reinforcing the Manistee River Viaduct. (14) July 19.
A Low-Cost Drawbridge.* (14) July 19.
Washington Street Bridge in Norwalk, Connecticut.* (14) July 26.
Pont St.-Georges sur la Lys à Gand.* L. Bonnet. (31) Pt. 1, 1913.
Les Grands Ponts Mobiles.* D. Bouckaert. (31) Pt. 1, 1913.
La Ligne de Miramas à l'Estaque; Le Viaduc de Caronte.* Canat. (43) May.
Sur la Stabilité des Systèmes Elastiques: Application d'une Nouvelle Methode à la Recherche de la Stabilité de certaines Parties Constitutives des Ponts.* S. Timochenko. (43) May.
Note sur les Travaux de Reconstruction du Pont *Charles-Albert*.* Houel. (43) May.
Pont Suspendu Fixe Système Gisclard sur la Luzège (Corrèze).* G. Leinekugel Le Cocq. (33) Serial beginning May 31.
Note sur un Nouveau Type de Pont en Maçonnerie.* Moreau. (35) July.

*Illustrated.

Bridges—(**Continued**).

Berechnung des Zweigelenkbogens und des gelenklosen Bogens auf Zeichnerischem Wege unter Verwendung des Castiglianoschen Satzes für beliebige Belastungen.* Hans Barkhausen. (81) Serial beginning Pt. 3.
Der Ersatz des Eisernen Uberbaues der Obern Limmatbrücke bei Wettingen (Schweiz).* E. Zingg. (69) Apr.
La Roche-Bernard-Strassenbrücke über die Vilaine (Frankreich).* Theodor Gesteschi. (69) Apr.
Bismarckbrücke in Saarbrücken.* (80) Serial beginning Apr. 19.
Die Statische Berechnung der Brücken in Gleiskrümmungen.* Siegmund Schwätzer. (69) May.
Zum Streit um das geistige Eigentum an dem preisgekrönten Entwurf im zweiten engeren Wettbewerb um eine Rhein-Strassenbrücke in Köln.* Mehrtens. (51) Serial beginning May 3.
Zur Begrenzung der Zugspannungen des Betons in Eisenbahnbrücken aus Eisenbeton.* I. A. Petry. (78) May 7.
Die Auswechslung von Brückentragwerken ohne Verwendung von Gerüsten.* Robert Schönhöfer. (53) May 9.
Zur Begrenzung der Zugspannungen des Betons in Eisenbahnbrücken aus Eisenbeton.* E. Probst. (40) May 17.
Ueber den Spannungszustand im Eisenbetonbalken infolge Beanspruchung durch eine Querkraft.* J. Lahrs. (78) May 26.
Ueber Brückenauswechslungen mit Besonderer Berücksichtigung Schweizerischer Verhaltnisse. Adolf Bühler. (69) Serial beginning June.
Der Zweite Engere Wettbewerb um den Bau einer Rheinstrassenbrücke in Köln.* Georg Chr. Mehrtens und Friedrich Bleich. (69) Serial beginning June.
Brücke über die Lahn bei Gräveneck.* D. Schluckebier. (78) June 12.
Strassenbrücke in Siegen (Westf.)* H. J. Kraus. (78) July 1.
Zum Bau der Walchebrücke in Zürich.* Fritz Locher. (107) July 5.

Electrical.

A Single-Phase Motor with Pole-Changing Windings.* J. S. Nicholson and B. Parker Haigh. (77) Apr.
The Aims and Work of the International Electrotechnical Commission. Silvanus P. Thompson. (77) Apr.
The Design of Apparatus for Improving the Power Factor of Alternating Current Systems.* Miles Walker. (77) Apr.
The Use of a Large Lighting Battery in Connection with Central Station Supply.* F. H. Whysall. (77) Apr.
Electrical Precipitation of Suspended Particles. Linn Bradley. (58) Apr.
The Change of Energy Loss with Speed in Continuous-Current Machines.* W. M. Thornton. (77) Apr.
The Desirability of Revising the Rating and Methods of Testing Electrical Apparatus. Benjamin G. Lamme. (4) Apr.
Half-Frosted Incandescent Lamps.* A. J. Makower and V. A. Oschwald. (73) Apr. 25.
Some Factors in the Parallel Operation of Alternators.* A. R. Everest. (77) May.
The Fourth Kelvin Lecture, the Ohm, the Ampere and the Volt: A Memory of Fifty Years, 1862-1912.* R. T. Glazebrook. (77) May.
Recent Developments in the Street Lighting of Manchester.* S. L. Pearce and H. A. Ratcliffe (77) May.
Some Problems in Traction Development Tramway Feeding Networks.* J. G. Cunliffe and R. G. Cunliffe. (77) May.
The "Knight" Public Fire-Alarm System. E. E. Moore. (77) May.
The Nature of Dielectric Fatigue.* W. Holttum. (77) May.
Mining Loads for Central Stations.* Wilfred Sykes and Graham Bright. (42) May.
Experiments with Furnace Electrodes. F. A. J. FitzGerald and A. T. Hinckley. (Paper read before the Am. Electrochemical Soc.) (105) May.
Automatic Substations.* H. R. Summerhayes. (42) June.
The Industrial Use of Synchronous Motors by Central Stations.* John C. Parker. (42) May.
Gas and Oil Engines for Electric Supply Stations. A. N. Rye. (26) May 2.
Resistance Coils for Alternating Current Work. H. L. Curtis and F. W. Grover. (Abstract from *Bulletin*, U. S. Bureau of Standards.) (73) May 2.
Automatic Voltage Regulation. W. J. Belsey. (Paper read before the Assoc. of Min. Elec. Engrs.) (22) May 2.
The Vickers Single-Battery Train-Lighting System.* (23) May 9.
The Uses of Artificial Insulating Materials in the Construction of Electrical Apparatus. H. Passavant. (Abstract of paper read before the Electrotechnische Verein.) (73) May 9.
Mockfjärd Hydroelectric Development, 20 000 Horsepower Plant in Sweden.* (14) May 10.
Subterranean Swedish Generating Plant.* (27) May 10.
Developments of a New Quartz-Tube Mercury Arc Lamp.* E. Weintraub. (27) May 10.

*Illustrated.

Electrical—(Continued).

McCalls Ferry Hydro-Electric Plant.* Charles H. Bromley. (64) May 13.
Power Supply on the Rand.* A. E. Hadley, M. I. E. E. (96) May 15; (77) June.
The Hysteresis Loop and Index.* W. M. Thornton. (73) May 16.
The Goldschmidt High-Power Wireless Station at Hanover.* (73) May 16.
Prices Charged for Electric Power. S. Simpson. (73) May 16.
Standardization Rules for Electrical Machinery. (Report of British Elec. and Allied Manufacturers' Assoc.) (73) May 16; (26) May 30; (47) May 23.
The Electrical Industry in France.* Georges Dary. (26) Serial beginning May 16.
The Betulander Automatic Telephone System.* (26) May 16.
New Works of the Cie. Parisienne de Distribution d'Electricité.* From *La Technique Moderne*.) (26) May 16.
Hydroelectric Plant for Sawmill Use at Hartland, Vt.* M. A. Hicks. (27) May 17.
Municipal Power Plant of Eugene, Ore.* (27) May 17.
The Hydro-Electric Development of the Braden Copper Co.* C. G. Newton. (13) May 22.
Automatic Device for Rating Current Meters.* George L. Stroebe. (13) May 22.
On the Use of Transformers with Mesh-Connected Secondaries for Earthing Three-Phase Systems.* G. W. O. Howe. (73) May 23.
Hydro-Electric Plant at Worcester.* (11) May 23.
Electrical Equipment of Industrial Plants.* Harry C. Spillman. (27) May 24.
The Theoretical Basis of the Multiple-Rate System.* Hugo E. Eisenmenger. (27) May 24.
High-Frequency Generator for Wireless Telegraphy and Telephony.* E. F. W. Alexanderson. (19) May 24.
An Essex Asylum Installation.* (26) May 30.
Rays of Positive Electricity.* J. J. Thompson. (Paper read before the Royal Soc.) (11) May 30.
Slinging and Handling Material.* (With Electric Cranes.) John Riddell. (Abstract from *General Electric Review*.) (16) May 31; (47) Apr. 25.
Electric Service in Chicago.* (27) May 31; (27) June 7.
Unified Public Utilities in Central Illinois.* (27) May 31.
The World's Largest Water-Power Plant at Keokuk.* (27) May 31.
Receiving Substation at St. Louis.* (27) May 31.
Electricity Direct from Coal.* Emil Baur. (From *Prometheus*.) (19) May 31.
The Commercial Aspect of Electric Cooking and Heating.* T. P. Wilmshurst. (77) June.
Economies in the Use of Electric Power.* W. E. Milns. (77) June.
The Formation of Deposits in Oil-Cooled Transformers. A. C. Michie. (77) June.
Some Recent Improvements in Continuous-Current Meters.* W. E. Cooke. (77) June.
Air-Cooled Jacketing in Hollow Walls by Electric Fans. J. W. Meares. (77) June.
Self-Synchronizing Machines.* E. Rosenberg. (77) June.
Seattle, Wash., Municipal Light and Power Plant.* J. D. Ross. (60) June.
The Behavior of Synchronous Motors During Starting.* F. D. Newbury. (42) June.
Test of an Artificial Aerial Telephone Line at a Frequency of 750 Cycles per Second. A. E. Kennelly and F. W. Lieberknecht. (42) June.
The Positive and the Negative Corona and Electrical Precipitation. W. W. Strong. (42) June.
The Electric Strength of Air.* J. B. Whitehead and T. T. Fitch. (42) June.
Law of Corona and Dielectric Strength of Air.* F. W. Peek, Jr. (42) June.
Constant Voltage Transmission.* H. B. Dwight. (42) June.
Theory of the Non-Elastic and Elastic Catenary as Applied to Transmission Lines. C. A. Pierce, F. J. Adams and G. I. Gilchrest. (42) June.
Automatic Methods in Long Distance Telephone Operation. H. M. Friendly and A. E. Burns. (42) June.
An Oscillograph Study of Corona.* Edward Bennett. (42) June.
The Production and Distribution of Energy.* Samuel Insull. (3) June.
Pasadena Municipal Lighting Plant. (60) June.
Wireless Telephone for Pit Use.* O. Dobbelstein. (From *Glückauf*.) (22) June 6.
A Theory of the Glow Discharge from Wires. J. S. Townsend. (73) June 6.
Condenser Telephones.* Karl Ort and Josef Rieger. (Abstract from *Archiv für Elektrotechnik*.) (73) June 6.
Hydro-Electric Power at Mason Valley, Nev.* Warren Aikens. (82) June 7.
Commercial Development Under Group Control, Illinois Northern Utilities Company.* (27) June 7.
Cost of Erecting 110 000 Volt Transmission Lines.* (27) June 7.
Aluminum Electrical Cables. (11) June 13.
Modern Converting Machinery.* (12) Serial beginning June 13.
Electricity Supply in London.* (73) June 13.
A Note on High Frequency Wave Filters.* G. M. B. Shepherd. (73) June 13.
Substation of Stockholm Municipal System.* E. Andreason. (27) June 14.

*Illustrated.

Electrical—(Continued).

Library Illumination.* F. A. Vaughn. (27) June 14.
Gas v. Electricity for the Lighting of Buildings. (24) June 16.
Electric Power for Quarries, Gravel Plants and Contract Work. (Report of Committee, National Elec. Light Assoc.) (13) June 19.
Sectionalizing Devices for Central Stations.* F. Heppenstall. (73) Serial beginning June 20.
Some Methods of Detecting Leakages on Alternating and Continuous-Current Systems.* R. D. Gifford. (26) June 20.
Quantitative Results of Recent Radio-Telegraphic Tests Between Arlington, Va., and U. S. S. *Salem*.* John L. Hogan, Jr. (27) June 21.
Hydro-Electric Systems. (Abstract from Report of Committee of the National Elec. Light Assoc.) (64) June 24.
Recent Developments at Stuart Street Station, Manchester.* (26) Serial beginning June 27.
Wiring of the Bankers' Trust Building.* (27) June 28.
Electrical Rehabilitation of the Rock Island Railroad Shops in Chicago.* (27) June 28.
The Compensating Quadrant Crane.* Harry W. Broady. (95) July.
Notes on Electric Field Distribution.* W. S. Franklin. (3) July.
Electrolytic Corrosion of Iron in Soils.* Burton McCollum and K. H. Logan. (42) July.
Operation of Frequency Changers.* N. E. Funk. (42) July.
Converting Substations in Basements and Sub-Basements.* B. G. Jamieson. (42) July.
Commutating-Pole Saturation in D.-C. Machines. Harold E. Stokes. (42) July.
Suggested Specifications for Testing High-Voltage Insulators. F. W. Peek, Jr., J. A. Sandford, Jr., and Percy H. Thomas. (42) July.
Some Experiments on Brush Contact Resistance.* Alfred Hay, M. H. Bhatt and J. M. Parikh. (73) July 4.
The Laying of Alternate Current Mains in Iron Pipes.* L. Bloch. (Abstract of paper read before the Elektrotechnische Verein.) (73) July 4.
A New Method of Hermetically Sealing Electrical Conductors Through Glass and Other Vitreous Substances. George B. Burnside. (73) July 4.
Hydro-Electric Power for B. C. Mines.* Jared Thompson. (82) July 5.
Electrical Equipment in Lytton Building, Chicago.* (27) July 5.
Phase Compensation.* Val. A. Fynn. (27) Serial beginning July 5.
Preservative Treatment of Poles. Russell A. Griffin. (Abstract of paper read before the National Elec. Light Assoc.) (13) July 10.
A Swiss Hydro-Electric Station Using Water Under 2 800 Ft. Head.* (13) July 10; (27) July 12.
The Generation of Electrical Energy for Smaller Towns. M. M. Inglis. (96) July 10.
A Siberian Wireless Station.* (26) July 11.
Submarine Power Transmission in the Baltic.* (26) July 11.
The Siemens Automatic Fast-Speed Printing Telegraph.* (73) July 11.
Carbon Electrodes for Electrolytic Cells. Joh. Harden. (73) July 11.
Safeguarding the Induction Motor.* (62) July 14.
Installation and Care of Storage Batteries. H. M. Nichols. (64) Serial beginning July 15.
Mercury Vapour Converters.* Maurice Leblanc, Jr. (73) July 18.
Transmission Experiments with Earth Antennæ.* F. Kiebitz. (From *Jahrbuch der drahtlosen Telegraphie*.) (73) July 18.
Fundamental Principles of Head-Lamp Illumination.* L. C. Porter and K. W. Mackall. (27) July 19.
Electric Wiring and Illumination of the Continental and Commercial Bank Building, Chicago.* (27) July 26.
Central-Station Practice at Waterloo, Iowa.* (27) July 26.
Savannah Electric Co.'s New Power Plant.* Warren O. Rogers. (64) July 29.
La Télégraphie sans Fil.* E. Girardeau. (32) Mar.
Appareil de Changement de Vitesse Electrique; Système Breslauer. (33) June 7.
L'Extension du Réseau Téléphonique de Paris.* G. Viard. (33) July 12.
Hochspannungskabel, Fabrikation, Eigenschaften und Prüfung.* Leon Lichenstein. (41) May 1.
Kreisdiagramme für Kaskadenschaltungen von Mehrphasen-Induktionsmotoren mit Kollektormaschinen.* H. Meyer-Delius. (41) May 1.
Postnebenstellen und Fernsprechanlagen nach dem Parallelsystem.* C. Beckmann. (41) May 8.
Schützensteuerungen zum selbsttätigen Anlassen von Motoren.* H. Cruse. (48) May 10.
Die Bedeutung der Metalldrahtlampe in der neuzeitlichen Beleuchtungstechnik.* M. v. Pirani. (40) May 14.
Elektrische Kransteuerungen.* R. Loder. (41) May 15.
Bemerkungen zum Entwurf elektrischer Maschinen für geräuschlosen Gang.* G. Pontecorvo. (41) May 15.

*Illustrated.

Electrical—(Continued).

Ueber eine Hochspannungsbatterie zur Messung sehr hoher Isolationswiderstände.* Alfred Wertheimer. (41) May 15.
Die Elektrizitätsversorgung von Gross-Berlin.* Bruno Thierbach. (41) May 22.
Ueber die öffentliche Beleuchtung der Stadt Dresden.* A. Strauss. (41) May 22.
Ein neues Verteilersystem mit zentraler Stromversorgung.* Victor J. Baumann. (41) May 22.
Der Wirkungsgrad des Elektromagneten.* L. Schüler. (41) Serial beginning May 29.
Ueber Prazisionswiderstände für hochfrequenten Wechselstrom. Karl Willy Wagner und Alfred Wertheimer. (41) Serial beginning May 29.
Die neueren elektrischen Lichtquellen. Berthold Monasch. (41) June 5.
Koronaerscheinungen an Leitungen.* Weidig und Jaensch. (41) Serial beginning June 5.
Die Verwendung des Elektrolyteisens im Elektromaschinenbau. Max Breslauer. (41) Serial beginning June 12.
Einiges aus grossen Hochspannungs-Freileitungsnetzen. August Petri. (41) June 19.
Verteilung elektrischer Energie über grosse Gebiete.* G. Klingenberg. (41) Serial beginning June 19.
Ueber einen neuen Torsionsmesser zur Bestimmung des Drehmomentes rotierender Wellen. H. Görges und P. Weidig. (41) Serial beginning June 19.
Der "Leistungsfaktor von Drehstrommotoren mit ungleicher Phasenbelastung."* P. Sauvage. (41) June 19.
Wert der Elektrischen Anlagen in Württemberg. H. Klaiber. (41) July 10.
Hochspannungs-Aussenenstallation der Central Georgia Transmission Co.* L. A. Magraw. (41) Serial beginning July 12.

Marine.

Engineering Applications of the Gyroscope.* Elmer A. Sperry. (3) May.
Arrangement of Boilers on Board Ship. J. Carson. (94) May.
Quadruple Screw Turbine-Driven Allan Liner *Calgarian.* (47) May 2.
Geared Turbine Steamers for the South Indian Railway.* (12) May 2; (23) May 9.
Spanish Transatlantic Liner *Infanta Isabel de Borbon.* (11) Serial beginning May 2.
Life-Saving at Sea.* Axel Welin. (29) May 9.
The French Atlantic Liner *Lutetia.** (12) May 9.
The First Triple-Turreted Warship.* Percival A. Hislam. (46) May 10.
Hydraulic Ash-Expeller for Ships.* (11) May 16.
The Japanese Battle-Cruiser *Kongo.** (11) May 23.
The French Battleships *Provence* and *Bretagne.** (12) May 23.
The Pendulum Propeller Rudder.* H. C. Vogt. (Abstract from *The Steamship.*) (19) May 24.
Manipulation of Cylinder Towers on a Drill Boat.* (14) May 31.
Why Not Channel Trolleys?* F. W. Fitzpatrick. (10) June.
Some Special Applications of Electricity on Warships. A. P. Pyne. (77) June.
Empirical Method of Screw Propeller Design. Peter Doig. (95) Serial beginning June.
Power Lifeboats, the Lundin Decked Type.* (95) June.
Side-Wheel Passenger Steamer *See-and-Bee.** (95) June.
German-Built Motor Ship *Hermann Krabb.** Alfred Gradenwitz. (95) June.
First American-Built Marine Diesel Engines.* (64) June 3.
S. S. *James Carruthers.** (96) June 5.
The Sperry Gyro Compass.* (26) June 6.
H. M. Torpedo-Boat Destroyers *Shark, Sparrowhawk* and *Spitfire.** (11) June 6.
Tests on a 10 000 Horse-power Fottinger Transformer, Hydraulic Gear for Marine Turbines.* Alfred Gradenwitz. (46) June 14.
The French Destroyer *Magon.** (12) June 20.
20 Horse-power Marine Oil Engine.* (12) June 20.
Armoured River Monitors for Brazil.* (12) June 20.
The Hamburg-Amerika Liner *Imperator.** (12) June 20; (11) June 20; (46) June 21; (64) July 8; (13) July 10.
Thirty-six Hours Under Water, A Submarine Propelled by Gasoline Engines While Submerged.* Charlton Lawrence Edholm. (46) June 21.
The French Dreadnought *Jean Bart.** (12) June 27.
The Isle of Man Geared-Turbine Steamer *King Orry.** (11) June 27.
The Electrical Propulsion of Ships. W. L. R. Emmet. (3) July.
Hudson River Steamer *Washington Irving.** (95) July.
New Pacific Coastwise Steamship *Congress.** (95) July.
A New Mail and Passenger Steamship for Newfoundland.* F. C. Coleman. (95) July.
A New Type of Submarine Boat. (95) July.
Boats and Davits for Saving Life at Sea.* (11) July 11.
The Tetrahedron Ship Model.* (12) July 18.
The Motor Ship *Christian X.* George Erichsen. (12) July 18.
The Greek Torpedo-Boat Destroyers of the *Lion* Class. (12) July 18.

*Illustrated.

Marine—(Continued).

The Salvage and Repair of the Steamship *Royal George*.* R. G. Skerrett. (46) July 26.

Les Navires Mouilleurs de Mines Sous-Marines *Pluton* et *Cerbère*.* Gouriet. (33) Apr. 26.

Note sur les Resultats d'Essais Faits au Sujet de la Construction des Remorqueurs et Chalands, Destinés aux Chantiers du Port de Bordeaux. Lefort. (43) May.

Lancement du Paquebot Anglais *Aquitania* et du Paquebot Allemand *Vaterland*.* (33) May 3.

Sonde à Signal et Appareil Suidois pour Découvrir les Bas-Fonds et les Mines Sous-Marines.* Emile Smith. (33) May 17.

L'Evolution des Navires du Type Croiseur.* (33) May 31.

Réducteur Hydraulique de Vitesse pour Turbine de 10 000 Chevaux, Système Foettinger.* (33) July 12.

Das Tankschiff *Hagen* erbaut von Fried. Krupp A.-G. Germaniawerft.* (48) Apr. 5.

Die neueste Ausführung des Föttinger-Transformators.* Wilhelm Spannhake. (48) Serial beginning May 10.

Mechanical.

Agglomeration of Fine Materials. Walter S. Landis. (56) Vol. 43.

Sintering and Briquetting of Flue-Dust. Felix A. Vogel. (56) Vol. 43.

The Schumacher Briquetting Process.* Joseph W. Richards. (56) Vol. 43.

The Briquetting of Iron-Ores.* N. V. Hansell. (56) Vol. 43.

The Rational Valuation and Quality-Efficiency of Furnace Stock. John Jermain Porter. (56) Vol. 43.

Progress in Roll-Crushing.* C. Q. Payne. (56) Vol. 43.

Flameless Combustion.* Carleton Ellis. (56) Vol. 43.

Vapour-Compression Refrigerating Machines.* J. Wemyss Anderson. (75) Nov., 1912.

A Contribution to the Theory of Refrigerating Machines.* John H. Grindley. (75) Nov., 1912.

Woodall-Duckham Verticals at the Poole Works.* (66) Apr. 29.

Chimney Draught and Its Influence on Producer Working.* Frederick Shewring. (66) Apr. 29.

Notes on the Recent Reconstruction of a Retort-House at Beckton.* Thomas Goulden. (Paper read before the Eastern Counties Gas Managers' Assoc.) (66) Apr. 29.

The Technics of the Ascension-Pipe. Edward G. Stewart. (Paper read before the London and Southern District Junior Gas Assoc.) (66) Apr. 29.

Standardization of Method for Determining and Comparing Power Costs in Steam Plants. H. G. Stott and W. S. Gorsuch. (42) May.

Numerical and Graphical Methods in Designing Involute Spur Gears.* A. Schien. (108) May.

The Industrial Application of Producer Gas to Brass Melting. B. M. Herr. (Paper read before the National Gas Engine Assoc.) (108) May.

Essentials in the Making of the Finer Steel Sheets. John G. Homan. (105) May.

The Heat Balance of the Open Hearth, an Account of an Elaborate Heat-Efficiency Test Made on Two 60-Ton Open Hearth Furnaces. Sidney Connell. (105) May.

The Manufacture of Petroleum Products.* F. C. Robinson. (58) May.

Fuel Saving and Smoke Prevention Thru the Use of a Smokeless Firebox Boiler. Robert W. Hunt. (60) May.

The Measurement of the True Static Pressure in a Moving Fluid, Application to an Aëroplane Barograph. A. F. Zahn. (3) May.

Motor Truck Efficiency.* (60) May.

Motor Tire Wear in Various Cities. (60) May.

Cost of Operating Motor Trucks. R. W. Hutchinson, Jr. (From *Power Wagon*.) (60) May.

The Sand and Gravel Plant of the Ohio Co.* (67) May.

Condensing Plant for Steam Turbines. J. A. McLay. (Paper read before the Assoc. of Min. Elec. Engrs.) (22) May 2.

Advantages of the Direct Method of Ammonia Recovery.* C. Heck. (From *Glückauf*.) (57) May 2.

Coal Washery and By-Product Coke-Oven Installation at Holmewood Colliery.* (22) May 2.

A French Diesel Engine.* (12) May 2.

The Bonecourt Process of Surface Combustion.* C. D. McCourt. (73) Serial beginning May 2.

Prime Movers and Condensing Apparatus.* Geo. E. Edwards. (82) May 3.

Boiler Troubles, Their Causes, and Their Prevention. Albert N. Dunlap. (Paper read before the National Assoc. of Steam Engrs.) (62) May 5.

Results of Concentration of Works. A. B. Walker. (Paper read before the North of England Gas Managers' Assoc.) (66) May 6.

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Mechanical—(Continued).

East Hull Carbonizing Plant Extensions with Notes on Working Results. R. Nelson. (Paper read before the North of England Gas Managers' Assoc.) (66) May 6.
Jacksonville Municipal Power Plant.* C. C. Austin. (64) May 6.
Testing Oil for Sulphur. William Pattern. (64) May 6.
Power Matters in Textile Mills. F. W. Dean. (Paper read before the National Assoc. of Cotton Manufacturers.) (64) May 6.
Cost of Pulling Small Trees with a Traction Engine. F. Hutchinson. (86) May 7.
Building an Automobile Every 40 Seconds.* Fred H. Colvin. (72) May 8.
Inspection Gages for Remington Gun Parts.* E. A. Suverkrop. (72) May 8.
The Smoke Problem From an Economic Standpoint. Charles W. Fulton. (Abstract of paper read before the Textile Inst.) (47) May 9.
On the Kinetic Theory of Gases.* Henry Cunyngham. (57) Serial beginning May 9.
The Manufacture of Motor Car Parts in America.* James McIntosh. (12) May 9.
Scale, Pitting and Corrosion in Steam Boilers; Their Cause, Effect and Remedy.* (22) May 9.
The Deformation by Centrifugal Stress of Turbine-Wheels.* (11) May 9.
Automatic Weaving Machinery.* (11) May 9.
Some Stationary British Diesel Engines.* (12) May 9.
The Railroad Man's Side of the Smoke Abatement Problems. G. M. Carpenter. (Paper read before the Cincinnati Ry. Club.) (62) May 12.
Recent Improvements in Methods of Gas Analysis. Leonard A. Levy. (66) Serial beginning May 13.
The LeBlond Heavy Duty Miller.* (72) May 15.
Strength of C-Shaped Cast-Iron Frames.* A. Lewis Jenkins. (72) May 15.
The Manufacture of White-Metal Die Castings.* (72) May 15.
Air as a Stimulator of Corrosion in Refrigerating Systems.* M. B. Smith. (13) May 15.
Tar and Its By-Products.* S. R. Church. (Paper read before the Southern Gas Assoc.) (83) May 15; (24) May 26; (66) May 27.
A New Manometer.* (12) May 16.
Benzol From Coal Gas. (11) May 16.
The Yarrow Boiler.* (11) May 16.
A New Boiler Furnace.* Charles W. Fulton. (From Paper "Smoke Prevention in Steam Boilers," read before the Textile Inst.) (12) May 16.
Steam Turbines with Special Reference to Mining Installations.* A. L. Ohlson. (Paper read before the Assoc. of Min. Elec. Engrs.) (22) May 16.
The Comparative Efficiency of Eiffel Surfaces, Studies in Aeroplane Design. Robert D. Andrews. (19) May 17.
The New Era in Machine Tool Designs. E. P. Bullard, Jr. (Abstract of paper read before the Cleveland Eng. Soc.) (62) May 19.
The First American Locomobile.* F. R. Low. (64) May 20.
Heine Boiler Tests at Terminal Station.* (64) May 20.
Low-Temperature Carbonization.* (66) May 20.
The Effects of Low Temperatures on Coal Gas and Air Gas. C. Aschof. (From *Zeitschrift für Beleuchtungswesen.*) (66) May 20.
Liquefied Products from Natural Gas. Irving C. Allen and George A. Burrell. (From *Technical Paper No. 10,* U. S. Bureau of Mines.) (66) May 20.
Diagram for Flow of Air in Pipes.* C. R. Richards. (From *Bulletin,* Eng. Exper. Station, Univ. of Illinois.) (86) May 21.
Plant of Henry Vogt Machine Company.* G. D. Crain, Jr. (20) May 22.
An Economical Sand and Gravel Plant.* (13) May 22.
Steel Castings and the Substitutes for Them.* Henry Souther. (20) May 22.
Machining the Ford Cylinders.* Fred H. Colvin. (72) Serial beginning May 22.
Punching and Shearing Values for Steel.* Gardner C. Anthony. (72) May 22.
A Pump Building Plant in California.* F. A. Stanley. (72) May 22.
Rollings Mills for Scrap Docks. G. G. Allen. (Paper read before the Ry. Storekeepers' Assoc.) (15) May 23; (18) May 24.
Storage and Handling of Ice. G. T. Dunn, Clarence Foster and D. C. Curtis. (Papers read before the Ry. Storekeepers' Assoc.) (15) May 23; (18) May 24.
Scientific Instruments: Their Design and Use in Aeronautics.* Horace Darwin. (Paper read before the Aeronautical Soc. of Great Britain.) (11) Serial beginning May 23; (12) June 13; (29) July 4.
A Visit to Lincoln Engineering Works.* (12) May 23.
Petrol and Alcohol Internal Combustion Engines. (11) May 23.
Liquid Fuel. Vivian B. Lewes. (29) Serial beginning May 23.
The Ostwald Process for Making Nitric Acid from Ammonia.* (22) May 23.
The "Notanos" Coal Washer.* (22) May 23.
Horizontal Tubular-Boiler Setting.* (27) May 24.
Reducing the Boiler Fuel in Water Gas Manufacturing. T. B. Genay. (Paper read before the Iowa District Gas Assoc.) (24) May 26; (83) July 15.
The Automatic Lighting and Extinguishing of Street Gas Lamps.* J. A. Seager. (24) May 26.
New Power Plant at Weber Wagon Works.* A. R. Maujer. (64) May 27.

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Mechanical—(**Continued**).

Results of Tests of Spiro Turbines.* Herbert Coward. (64) May 27.
The Illmer Two-Stroke-Cycle Gas Engine.* (64) May 27.
Cooling Tower for Small Refrigerating Plant.* R. L. Mossman. (64) May 27.
Description of the Wandsworth Gas Works.* (66) May 27.
Performance of a 450-H. P. Boiler with Oil Fuel.* A. L. Menzin. (13) May 29.
A New Hydraulic Transmission Gear.* (20) May 29.
Steel Castings from the Electric Furnace.* Edwin F. Cone. (20) May 29.
The Gas Engine in the Steel Industry. Heinrich J. Freyn. (Paper read before the Am. Iron and Steel Inst.) (20) May 29; (47) June 13; (22) June 27.
Experience with the Single Gas-Driven Blower. Arthur West. (Paper read before the Am. Iron and Steel Inst.) (20) May 29.
The Pendulameter: A New Shop Instrument.* (72) May 29.
Automatic Control of Machine Drives.* H. F. Stratton. (72) May 29.
Heat Accumulators and Their Use in Exhaust Steam Turbine Plants.* A. Alison. (Abstract of paper read before the Junior Inst. of Engrs.) (47) May 30.
Application and Production of Die Castings for Automobiles.* Walter Betterton. (Paper read before the Inst. of Automobile Engrs.) (47) Serial beginning May 30.
Case-Hardening. David Keachie. (Abstract of paper read before the Scientific Soc., Royal Technical College.) (47) May 30.
Production of Coal from Cellulose at High Temperatures and Pressures. F. Bergins. (Paper read before the Soc. of Chemical Industry.) (22) May 30.
Small Steam Turbines.* (12) May 30.
The Shuman-Haines Steam Engine.* (12) May 30.
A Portable Coal and Coke Handling Machine.* (22) May 30.
1 000 Horse-power Four-Cylinder "Premier" Gas Engine. (11) May 30.
Recent Activity in the Explosive Pump Art.* (46) May 31.
Safety, Relief, Sanitation and Welfare in a Great Corporation (U. S. Steel Corporation.)* (98) June.
The Production of Sound Steel Ingots.* (Simonds Mfg. Co.) (105) June.
Comparative Notes on Independent Steam Condensing Plants.* W. A. Dexter. (77) June.
The Great Economies Produced by Continuous Foundry Installations. George K. Hooper. (Paper read before the Am. Foundrymen's Assoc.) (108) June.
Sub-Bituminous and Lignitic Coal.* Samuel B. Flagg. (Abstract of paper read before the Ry. Fuel Assoc.) (25) June; (47) June 27; (15) May 30; (13) June 12; (18) June 7.
Stress Considerations in Aeroplane Design. A. F. Zalim. (3) June.
Langerfeld Coal and Slate Separator.* Arthur Langerfeld. (45) June.
Best Methods of Welding Superheating Tubes and Tools Used for Same.* (Abstract of Report of Committee, Master Boiler Makers' Assoc.) (94) June.
The Advantages and Disadvantages of Using Oxy-Acetylene and Electric Welding Process for Boiler Maintenance and Repairs. (Abstract of Report of Committee, Master Boiler Makers' Assoc.) (94) June.
Is There Any Limit to the Length of a Tube in a Boiler Without a Support Midway of Boiler, Etc.? (Abstract of Report of Committee, Master Boiler Makers' Assoc.) (94) June.
Methods for Investigating and Recording Atmospheric Impurities, Including the Soot and Dust Suspended in the Atmosphere.* John B. C. Kershaw. (105) June.
The Problem of Smoke Abatement.* William A. Hoffman. (Paper read before the Engrs'. Club of St. Louis.) (1) June.
Burns 30 000 Bricks in 24 Hours.* (Buhrer Shortened Continuous Kiln.) (76) June 1.
The Control of Fire Clay.* (76) June 1.
Standard Boiler and Fire Box Requirements of Cleveland Smoke Inspection Division.* (62) June 2.
Some Notes on the Chemistry of Gas Coal. E. F. Wilson. (Paper read before the New England Assoc. of Gas Engrs.) (24) Serial beginning June 2.
Gas Engines and Their Applications.* William H. Edmondson. (Paper read before the N. C. G. A.) (83) June 2.
Experiments on Efficient Boiler Operation. B. W. Rogowski. (64) June 3.
Coal and Ash Handling at Lake Shore Plant.* A. D. Williams. (64) June 3.
A German Soot and Cinder Arrester.* Otto E. Trautman. (64) June 3.
Some Notes on Carbonization. Ernest A. Franks. (Paper read before the Wales and Monmouthshire District Institution of Gas Engrs.) (66) June 3.
The Packard Motor Car Company, Detroit.* (20) Serial beginning June 5.
Making Cylinders on Semiautomatic Machines.* (72) June 5.
Operation of Balance Indicating Machine.* (72) June 5.
Design of Structural Steel Plant.* E. H. Darling, A. M. Can. Soc. C. E. (96) Serial beginning June 5.
Lang's Lathe Works at Johnstone.* (11) June 6.
A Modern Sheet Metal Shop and Cost System.* (101) June 6.
The John Samuel White Diesel Engine.* (12) June 6.
The Sperry Aeroplane Stabiliser.* (12) June 6.

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Mechanical—(Continued).

Chemical Treatment of Waste Wood.* H. K. Benson. (Paper read before the Inter. Congress of Applied Chemistry.) (19) June 7.
The Modern By-Product Coke Oven. C. A. Meissner. (Paper read before the Am. Iron and Steel Inst.) (62) June 9.
The Ohio Board of Boiler Rules and Its Work. H. A. Baumhart. (Paper read before the Cleveland Eng. Soc.) (62) June 9.
A Laboratory Method of Fractionating Coal to Determine its Output of Gas and By-Products.* Q. Schramm. (From *Journal für Gasbeleuchtung.*) (24) June 9; (66) May 6.
New Coal Gas Plant at Atlanta, Ga.* R. C. Congdon. (Paper read before the Southern Gas Assoc.) (24) June 9; (83) June 2.
Some Notes on the Vertical Retorts at Derby, Conn. Charles H. Nettleton. (Paper read before the New England Assoc. of Gas Engrs.) (24) June 9.
Coal Gas? Surely. But How? R. B. Brown. (Paper read before the New England Assoc. of Gas Engrs.) (24) June 9.
Testing Small Steam Turbines.* R. C. Allen. (64) June 10.
The Flow of Steam Through Pipes.* H. V. Carpenter. (64) June 10.
Estimating Heat Value of Fuel.* (64) June 10.
Engine-Cylinder Lubrication.* Willis Lawrence. (64) June 10.
Manufacture and Uses of Malleable Cast Iron.* Enrique Touceda. (Paper read before the Soc. of Automobile Engrs.) (20) June 12.
Gas and Oil Engines for Electric Supply Stations. A. N. Rye. (96) June 12.
Machining the Petter Crude Oil Engine.* I. W. Chubb. (72) Serial beginning June 12.
Points on Gas-Fired Boilers.* K. Huessener. (22) June 13.
Recent Progress in Industrial Pyrometry.* Chas. R. Darling. (12) June 13.
Steam-Hydraulic Slab Shears.* (12) June 13.
Messrs. G. and J. Weir's Works at Cathcart.* (11) June 13.
New Diesel Plant at Kingston-on-Thames.* (26) June 13.
A Plea for Higher Pressure in Distribution.* J. E. Bullard. (83) June 16.
Uncertain Cost of Natural Gas Production and Transportation. George Heard. (Paper read before the Natural Gas Assoc.) (83) June 16.
Natural Gas Progress. Martin Benson Daly. (83) June 16.
Measuring the Flow of Natural Gas. D. Hastings. (Paper read before the Natural Gas Assoc.) (83) June 16.
Stimulating the Gas Lighting Business. (Paper read before the New England Assoc. of Gas Engrs.) (24) June 16.
Operating a Water Gas Machine by Electric Pyrometer. F. L. Weisser. (Paper read before the S. W. Electrical and Gas Assoc.) (83) June 16; (24) July 7.
Gas *v.* Electricity for the Lighting of Buildings. (24) June 16.
Diagnosis of Steel Truck Wheels.* George Walther. (62) June 16.
The Walther Feld Process for the Manufacture of Sulphate of Ammonia.* A. Pacchioni. (Paper read before the Italian Gas and Water Assoc.) (66) Serial beginning June 17.
The Standard Specification of Street Lighting.* W. J. Liberty. (From *The Illuminating Engineer.*) (66) June 17.
Steam-Loop and Gravity-Return System (Steam Plant.)* J. C. Hawkins. (64) June 17.
Layout, Design and Equipment of Industrial Plants. A. Home-Morton. (Paper read before the Liverpool Eng. Soc.) (96) June 19.
Jacket Water Temperatures and Fuel Consumption in Internal Combustion Engines.* Reginald Trautschold. (96) June 19.
Notes on Gaseous Heating.* E. W. Smith and C. M. Walter. (Abstract of paper read before the Institution of Gas Engrs.) (47) Serial beginning June 20; (66) June 24.
Vaporiser for Open-Hearth Suction Producers.* (47) June 20.
A New Law of Vulcanization, the Physical Chemistry of Rubber Manufacture. Augustus O. Bourn. (Paper read before the Inter. Rubber Exhibition.) (19) June 21.
Manufacture of Pipe for Oil and Gas.* F. N. Speller. (Abstract of paper read before the Natural Gas Assoc. of America.) (24) June 23.
Bureau of Standards' Rules for Gas Service. (Report to the Wisconsin R. R. Comm.) (24) June 23.
The Illmer Gas Engine; A New Factor in the Steel Works Power Field.* (62) June 23.
Liquid Purification. W. B. Davidson. (Paper read before the Institution of Gas Engrs.) (66) June 24.
Notes on Suburban Gas Supply.* A. A. Johnston. (Paper read before the Institution of Gas Engrs.) (66) June 24.
Depreciation; Estimated and Actual. Alex. C. Humphreys. (Paper read before the Institution of Gas Engrs.) (66) June 24.
Power Plant of Woolworth Building.* Thomas Wilson. (64) June 24.
Refrigeration a Desirable Load for Central Stations. (Abstract from Report of Committee, National Elec. Light Assoc.) (64) June 24.
Heat Balance of a Producer. Julian C. Smallwood. (64) June 24.

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A New Electrically Driven Sheet Mill.* (20) June 26.
The Works of Messrs. Reavell and Co., Limited.* (11) June 27.
Coppee By-Product Coke-Oven Installation at Lancaster's Steam Coal Collieries, Cwmtillery.* (22) June 27.
Ammonia Stills in By-Product Coke-Oven Plants.* A. Thau. (From *Glückauf.*) (22) Serial beginning June 27.
Manufacture of Switches and Frogs.* (18) Serial beginning June 28.
A Large Gas-Pump Installation.* (103) June 28.
The By-Products of Sugar Manufacture and Methods for Their Utilization. C. A. Browne. (6) July.
The Conservation of the Worker (U. S. Steel Corporation). Arundel Cotter. (9) July.
Denatured Alcohol as a Decarbonizer and Engine Cleanser. Joseph Anglada. (108) July.
Motor Trucks in Municipal Contracting.* H. W. Perry. (60) July.
The Adaptability of Electric Welding.* George Hills. (105) July.
Riegel Watertube Firebox Design.* S. S. Riegel. (94) July.
Construction of Underfired Boilers.* W. E. Pinnegar. (94) July.
Industrial Combustible Gases.* J. M. Rusby. (3) July.
The Pishel Coking Test.* Max A. Pishel. (45) July.
Sand and Gravel Washing Plants.* Raymond W. Dull. (Paper read before the National Assoc. of Cement Users.) (67) July.
Woodworking Machinery for Railway Carriage and Wagon Building.* George Fisher. (21) Serial beginning July.
Electrical Requirements of Certain Machines in the Rubber Industry.* C. A. Kelsey. (42) July.
Mixed-Pressure Steam Turbine. L. G. Hamner. (Abstract of a paper read before the Melville Council No. 9, Universal Craftsmen.) (64) July 1.
Decomposition of Carbon Bisulphide in Coal Gas by Hot Purification.* Charles Claude Carpenter. (Paper read before the Societe Technique du Gaz.) (66) July 1.
A 34 Passenger Single-Deck Motor Omnibus.* (13) July 3.
A Six-Story Continuous Foundry Building (The Ford Motor Co.).* Oliver J. Abell. (20) July 3.
Report on the Conditions of Work in Cleaning Steam Boilers and Flues. J. H. Warren. (47) July 4.
Gas Engine Practice. W. Fennell, M. Inst. C. E. (Abstract of paper read before the Birmingham Dist. Elec. Club.) (47) July 4.
The Working Fluid of Internal Combustion Engines.* Dugald Clerk, M. Inst. C. E. (Paper read before the Junior Inst. of Engrs.) (11) Serial beginning July 4; (47) July 11; (12) July 11.
Queen's Engineering Works, Bedford.* (12) July 4.
Blast-Quantity and Pressure in Cupola Working. F. J. Cook. (Paper read before the British Foundrymen's Assoc.) (22) July 4.
Fuel Production in the United States.* R. H. Byrd. (46) July 5.
Pneumatic Tires. P. W. Litchfield. (From *Bulletin*, Society of Automobile Engineers.) (19) July 5.
Foundry-Cupola Gases and Temperatures.* A. W. Belden. (Paper read before the Am. Foundrymen's Assoc.) (62) July 7.
Power Plant of the Otis Building.* A. R. Maujer. (64) July 8.
Refractory Material in Gas-Works. Thomas Holgate, M. Inst. C. E. (66) Serial beginning July 8.
The Cost of Generating Power with Diesel Oil Engines. Gordon Kribs. (96) July 10.
Artificial Ice Manufacture in Ottawa.* Gerald L. Kirwan. (96) July 10.
A Complete Elevator Manufacturing Plant.* (20) July 10.
The Machinery of the Parker Gun Barrel.* Ethan Viall. (72) July 10.
The Sturtevant Steam Turbine.* (11) July 11.
Cost Data on Motor Trucks Used to Haul a Contractor's Supplies. (14) July 12.
Production of Malleable Castings. Richard Moldenke. (Paper read before the Am. Chemical Soc.) (62) July 14; (47) July 18.
Coke-Oven Carbonization.* W. Chaney. (Paper read before the British Institution of Gas Engrs.) (24) July 14; (22) June 27; (57) July 18; (66) June 24.
Recent Developments in Industrial Fuel Appliances. E. C. Weisgerber. (Paper read before the Iowa Dist. Gas Assoc.) (24) July 14.
Burns Brick Without Grate.* Paul Beer. (76) July 15.
The Technical Development of the Heating of Gas-Making Settings. Karl Bunte. (Abstract of paper read before the German Assoc.) (66) July 15.
Manufacture of Oil Gas.* E. C. Jones. (83) July 15.
Clay-Working Machines of the Past and Present.* (76) July 15.
Ingot Iron. (Manufactured by American Rolling Mill Co.)* (15) July 18.
Spring Design.* J. St. Vincent Pletts. (12) July 18.
The Works of Messrs. Ransomes and Rapier, Limited.* (11) July 18.
A Floating Pneumatic Elevating and Grain Discharging Plant.* Frederick C. Coleman. (46) July 19.

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A Machine for Blowing Window Glass.* (46) July 19.
The Scientific Advancement of the Canning Industry.* R. T. Mohan. (Paper read before the Canadian Section of the Society of Chemical Industry.) (19) July 19.
The Principles of Fuel Oil Engines.* C. F. Hirshfeld. (Paper read before the Society of Agricultural Engrs.) (19) Serial beginning July 19.
Improved Methods of Connecting Small Turbines in Steam Power Plants and Exhaust Steam Heating and Drying Systems.* George H. Gibson. (62) July 21; (98) Apr.
The Big Ford Gas Engine.* F. R. Low. (64) July 22.
Duchesne's Experiments on Superheat. R. C. H. Hock. (64) July 22.
Heat-Treated Automobile Frame Steel.* D. K. Bullens. (20) July 24.
Machining and Assembling Automobile Engines, Continental Motor Mfg. Co.* Harry C. Spillman. (20) July 24.
The Production of Synthetic Ammonia.* F. Haber and R. Le Rossignol. (Abstract from *Journal*, Society of Chemical Industry.) (19) July 26.
Duplex *vs.* Straight-Line Construction in Air Compressors.* R. L. Doncon. (62) July 28.
Removal of Carbon Bisulphide by Hot Purification (Purification of Coal Gas).* Charles C. Carpenter. (Paper read before the Soc. Tech. du Gaz en France.) (24) July 28.
The Flat-Curve Engine.* A. D. Skinner. (64) July 29.
Economy of Compression in Steam Engines. Robert R. Fisher. (64) July 29.
Effect of Variable Load on Gas Producers. Reginald Trautschold. (64) July 29.
Machines Rotatives à Très Grandes Vitesses (Turbines, Compresseurs et Dynamos).* Maurice Leblanc. (32) Feb.
Les Dirigeables Rigides *Spiess* et *Zeppelin:* Les Flottes Aériennes Française et Allemande.* G. Espitallier. (33) Mar. 17.
Théorie Générale des Régimes de l'Aéroplane.* Georges de Bothezat. (37) Apr.
Examen de la Méthode du Professeur Clayton pour l'Etude des Machines à Vapetur à Piston. Dwelshauvers-Dery. (37) Apr.
Freins Hydrauliques pour l'Etude des Turbines à Vapeur.* A. Rateau. (32) Apr.
De l'Ecrouissage. P. Galy-Ache. (93) May.
Sur l'Ecrouissage.* Hanriot. (93) May.
Recherches sur le Recuit des Produits Ecrouis. Léon Guillet. (93) May.
Causes et Effets des Allumages Prématures dans les Moteurs à Explosion et à Combustion.* L. Letombe. (32) May.
Presse Hydraulique de 80 Tonnes pour Essais de Matériaux; Système Ch. Monin.* (34) May.
Chaudiéres à Vapeur pour Brûler le Fraisil des Boités à Furnée.* (34) May.
Le Rôle des Basses Températures dans l'Industrie de la Fixation de l'Azote.* Georges Claude. (32) May.
Sur la Possibilité de Quelques Perfectionnements à l'Aéroplane.* L. Constantin. (32) May.
Marteaux-Pilons Pneumatiques.* A. Ihne. (37) May.
Résultats d'Essais de Condenseurs à Surface Exécutés à la Centrale Electrique de Feijenoord, près Rotterdam.* (37) June.
Laminoir Réversible à Commande Electrique de la Skinningrove Iron Co. (Angleterre).* (33) May 17.
L'Ejectair Breguet.* Maurice Delaporte. (92) June; (32) May.
Le Funiculaire Aérien à Voyageurs de Lana au Vigiljoch (Tyrol).* (33) June 7.
Le 1er Congrès Français et l'Exposition de Fonderie, 1913.* P. Calfas. (33) June 7.
Contribution à l'Etude de l'Influence du Recuit sur la Structure des Alliages.* A. Portevin. (93) June.
Recherches sur le Développement des Grains des Métaux par Recuit après Ecrouissage.* Felix Robin. (93) June.
Développement des Grains de Recuit dans les Alliages.* Felix Robin. (93) June.
Influence de l'Etirage sur les Propriétés des Produits Métallurgiques. Léon Guillet. (93) June.
La Construction des Hydroaéroplanes; Concours de Monaco (April, 1913) et de Deauville (Août, 1913.)* A. Delaunay. (33) Serial beginning June 21.
Nouveaux Perfectionnements dans la Fabrication du Coke.* Henry Thiry. (93) July.
Les Alliages d'Aluminum et de Zinc.* Rosenhain et Archbutt. (93) July.
Die Erzeugung von Zusatzwasser zur Kesselspeisung durch Verdampferapparate im Betriebe ortfester Anlagen.* A. Höpfl. (48) Mar. 22.
Versuche über den Kraftverbrauch von Fördermitteln.* Georg von Hanffstengel. (48) Mar. 22.
Die Herstellung kinematographischer Bilder in Fabriken.* G. A. Fritze. (48) Mar. 22.
Die Durchführung und das Ergebnis des Wettbewerbes um den Kaiserpreis für den besten deutschen Flugzeugmotor.* F. Bendemann. (48) Serial beginning Mar. 29.
Neuerungen im Bau von Löffelbaggern.* R. Richter. (48) Mar. 29.

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Ueber die statische Längsstabilität der Drachenflugzeuge.* Carl Wieselsberger. (48) Mar. 29.
Die Neuere Entwicklung des Schaufelbaggers.* Hubert Hermanns. (53) Apr. 4.
Diagramm-Charakteristiken.* Bruno Leinweber. (48) Apr. 5.
Kalt-Kreissägemaschinen mit hoher Arbeitsleistung. (48) Apr. 12.
Die Kohlenförder- und Stapelanlagen der Soc. Anon. les Transport de Savone. Albert Pietrkowski. (48) Apr. 12.
Einheitsfarben zur Kennzeichnung von Rohrleitungen in industriellen Betrieben. (7) Apr. 19.
Zur Berechnung von Schutzbrücken für Drahtseilschwebebahnen. Walter Müller. (40) Apr. 19.
Schwinden und Lunkern des Eisens.* (50) Apr. 24.
Die Unterkühlung beim Ausfluss gesättigten Dampfes.* A. Stodola. (107) Apr. 26.
Neuere amerikanische Verladeanlagen für Erze und Kohlen.* A. Bergman. (48) Serial beginning Apr. 26.
Die Adolf-Emil-Hütte in Esch.* (50) May 1.
Die Luftschiffhalle im Luftschiffhafen zu Potsdam ausgeführt von der Maschinenfabrik Augsburg-Nürnberg, A.-G., Werk Gustavsburg.* (48) May 3.
Zeichnerische Untersuchung der Gemischbildung in Gasmaschinen.* J. Magg. (48) May 3.
Die Schwebebahn Lana-Vigiljoch.* G. Fühles. (48) Serial beginning May 10.
Koksersparnisse bei Zentralheizung. G. de Grahl. (7) May 17.
Schottenöfen und Oefen zum Brennen von Brechschutt.* (80) May 24.
Ueber die Grundlagen zur Ermittlung des Arbeitsbedarfes beim Schmieden unter der Presse.* Fr. Riedel. (48) May 31.
Die Grundlagen für die Entwicklung der Flugtechnik im Jahre 1913.* Roland Eisenlohr. (48) May 31.
Die Fortschritte deutscher Stahlwerke bei der Herstellung hochlegierter Schnellarbeitsstähle. G. Schlesinger. (50) June 5.
Motorwagen mit Vierräderantrieb.* A. Heller. (48) June 7.
Amerikanische Setzmaschinen.* R. Neumann and R. Blumenfeld. (48) June 7.
Ueber die Gewinnung von Ammoniumsulfat mit Hilfe des in den Kokereigasen enthaltenen Schwefels.* J. Reichel. (50) Serial beginning June 12.
Ueber die Entwicklung der Gasöfen zum Brennen von Kalk. A. Mendheim. (80) June 14.
Abdampfverwertung.* Fritz L. Richter. (41) June 19.
Die Messung des Kohlenverbrauchs von Drehrohröfen durch die Rauchgas-Analyse. Hans Kuhl und Wilhelm Michaëlis. (80) June 21.
Ein Beitrag zur Frage der Heizflächenbewertung bei gusseisernen Gliederkesseln. O. Steinhaus. (7) June 21.
Dampfverbrauch einer Kalksandsteinfabrik.* A. Rüster. (80) June 26.
Elektrische Walzenstrassenantriebe.* C. Hahn. (41) Serial beginning July 3.
Hulett-Entlader und ihre Verwendbarkeit in Deutschland.* Richard Borchers. (50) July 3.
Ueber Walzenzugmaschinen.* C. Kiesselbach. (50) July 17.

Metallurgical.

Electrical Fume-Precipitation.* F. G. Cottrell. (56) Vol. 43.
The Decomposition of Metallic Sulphates at Elevated Temperatures in a Current of Dry Air.* H. O. Hofman and W. Wanjukow. (56) Vol. 43.
The Direct Determination of Small Amounts of Platinum in Ores and Bullion. Frederic P. Dewey. (56) Vol. 43.
The Solubility in Nitric Acid of Gold Contained in Certain Copper-Alloys (Copper-Bullions.) Edward Keller. (56) Vol. 43.
Abrasion and Dust-Losses in Ore-Drying.* Carl F. Dietz and Dyke V. Keedy. (56) Vol. 43.
The Sintering of Fine Iron-Bearing Materials by the Dwight & Lloyd Process.* B. G. Klugh. (56) Vol. 43.
Electrostatic Concentration on Separation of Ores.* Henry A. Wentworth. (56) Vol. 43.
The James Diagonal-Plane Slimer.* S. Arthur Krom. (56) Vol. 43.
The Refining of Blister-Copper. Horace H. Emrich. (56) Vol. 43.
The Treatment of Complex Silver-Ore at the Lucky-Tiger Mine, El Tigre, Sonora, Mexico.* D. L. H. Forbes. (56) Vol. 43.
Ore-Treatment at Republic, Wash.* Francis A. Thomson. (56) Vol. 43.
The No. 2 Unit of the Mill of the Bunker Hill Sullivan Mining & Contracting Co. R. S. Handy. (56) Vol. 43.
The Macquister-Tube Flotation Process.* O. B. Hafstrand. (56) Vol. 43.
The San Poil Mill, Republic, Wash. Edward C. Morse. (56) Vol. 43.
The Chemistry of Tungsten. Chas. Baskerville. (Abstracts of a paper read before the New York Elec. Soc.) (105) May.
Manhattan Ore Milling Co.'s Mill, Nevada.* J. C. Kennedy. (82) May 3.

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Continuous Agitation at the West End Mill, Tonopah.* Jay A. Carpenter. (103) May 3.
Concentration of Low-Grade Iron Ores.* Frank E. Shephard. (82) May 10.
The Analysis of Smelter Contracts. Gelasio Caetani. (Paper read at Harvard University.) (103) Serial beginning May 10.
Aluminium Precipitation at Nipissing.* E. M. Hamilton. (16) May 10.
Dust Determination for Blast-Furnace Gas. Everard Brown. (64) May 13.
Smelting Raw Black Jack in the Fink Smelter.* H. B. Pulsifer. (82) May 17.
Cyaniding at Grass Valley, California.* Herbert A. Megraw. (16) May 17.
Grinding Pans at Kalgoorlie.* M. W. von Bernewitz. (103) May 17.
The Pinder-Berry Stamp-Mill.* S. L. Berry. (103) May 17.
The Copper Smeltery of the U. S. Metals Refining Co.* Richard H. Vail. (16) May 24.
Grading Analyses and Their Application to Cyanidation. John W. Bell. (From *Bulletin*, Canadian Min. Inst., March, 1913.) (16) May 24.
Blanket Concentration of Cyanide Solutions.* John Gross. (103) May 24.
Zinc-Dust Precipitation at Cerro Prieto.* H. S. Munroe. (16) May 31.
The Electric Furnace for Zinc Smelting.* Peter E. Peterson. (82) Serial beginning May 31.
Copper Smelting Operations of the Santa Fe Gold and Mining Co.* Clarence T. Emrich. (105) June.
Zinc-Dust Precipitation Equipment.* Donald F. Irvin. (103) June 7.
Slow-Speed Milling. E. E. Carter. (103) June 7.
Selection and Operation of Tube Mills.* A. M. Merton. (82) June 14.
Conditions Governing Washing of Filter Cakes.* A. W. Warwick. (82) June 14.
Continuous Agitation with Barren Cyanide Solution.* C. F. Spaulding. (103) June 21.
Milling in Southeastern Missouri.* Claude T. Rice. (16) Serial beginning June 21.
The Action of Oxidizers in Cyaniding. Morris Green. (From *Journal*, Chem. Met. and Min. Soc., South Africa.) (16) June 21.
Lubrication at Steptoe Concentrator. A. G. Marsh. (16) June 21.
Alloying of Aluminum. C. H. Ivinson. (Paper read before the British Foundrymen's Assoc.) (47) June 27.
Electric Smelting as Conducted at Heroult. John Crawford, Jr. (Abstract of paper read before the Min. Congress of Northern California and Southern Oregon.) (103) June 28; (105) July.
Lowering Furnace-Flux Costs (for Smelting). C. A. Tupper. (82) June 28.
Specifications and Tests for Zinc Dust. A. M. Merton. (82) June 28.
Smelting in Shaft Furnaces at Great Altitudes. Vincente Pazos y Sacio. (6) July.
Notes on Alloy Steels. H. C. Williamson. (108) July.
Electro-Analysis of the Copper Alloys.* J. G. Fairchild. (105) July.
Cyanide Practice in the Black Hills, South Dakota. H. C. Parmelee. (105) Serial beginning July.
The Purification of Blast Furnace Gases.* C. Herwegh. (Paper read before the Société Industrielle de l'Est.) (105) July.
The Gold Road Cyanide Mill, Arizona.* Herbert A. Megraw. (16) July 5.
The Kedabeg Copper-Smelting Works.* O. H. Hahn. (From *Glückauf*.) (16) July 5.
A Simple Plant for Testing Efficiency.* A. T. Tye. (103) July 12.
The Electrolytic Refinery at Trail, B. C.* (82) July 12.
Principles and Methods of Ore Testing. I. F. Laucks. (16) July 12.
Blast Quantity and Pressure in Cupola Working. F. J. Cook. (Paper read before the British Foundrymen's Assoc.) (47) July 18.
Underestimating the Cost of Milling Plants. A. Sydney Additon. (103) Serial beginning July 19.
The Symmes Agitator.* Whitman Symmes. (103) July 19.
Lead Refining Plant at South Chicago.* H. B. Pulsifer. (82) July 26.
Les Hauts-Fourneaux Electriques de Trollhattän et Hagfors (Suêde). P. Nicou. (93) June.
Die Entschwefelung des Eisens, ihre Gesetze und deren Anwendung.* W. Heike. (50) Serial beginning May 8.
Grundlagen für das richtige Entwerfen von Ofenanlagen.* (50) Serial beginning May 22.
Verwendung und neuere Anordnung der Zweischienenhängebahn. Engelbert Leber. (50) May 29.
Ueber Mittel zur Verhütung von Roheisendurchbrüchen bei Hochöfen.* (50) June 12.
Ueber eine bemerkenswerte Kupolofen-Explosien.* Richard Fichtner. (50) June 26.
Kupolofenanlange mit kippbaren Vorherden.* Edmund Neufang. (50) June 26.
Ein neuzeitliches Gasumsteuerventil für Regenerativöfen.* W. Reitmeister. (50) July 3.
Die Fortschritte deutscher Stahlwerke bei der Herstellung Hochlegierter Schnellarbeitsstähle.* G. Schlesinger. (50) July 17.

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Military.

Sea and Air Command, Germany's New Policy in Its Relation to the British Naval Supremacy.* (From the *Fortnightly Review.*) **(19)** June 21.
A Two-Company Field Work.* F. B. Wilby. **(100)** July.

Mining.

Electric Hoist at Hecla Mine, Burke, Idaho.* E. M. Murphy. **(56)** Vol. 43.
Efficiency-Engineering Applied to Mining. Glenville A. Collins. **(56)** Vol. 43.
Mining-Methods at Nacozari, Sonora, Mexico.* D. C. Livingston. **(56)** Vol. 43.
Replaceable Lips for Elevator-Buckets.* H. J. Maguire. **(56)** Vol. 43.
A New Electric Miners' Lamp.* D. B. Rushmore. **(56)** Vol. 43.
Suggestions on the Development of New Colliery Districts, with Special Reference to the Support of the Surface.* Hubert Bradshaw. (Paper read before the South Staffordshire and Warwickshire Inst. of Min. Engrs.) **(106)** Vol. 45, Pt. 2.
Testing of Fans: A Plea for Standardized Test Conditions.* John Watson. (Paper read before the Min. Inst. of Scotland.) **(106)** Vol. 45, Pt. 2.
Some Recent Experiments with Internal Pressure in Pneumatophors.* Harold C. Jenkins. (Paper read before the South Staffordshire and Warwickshire Inst. of Min. Engrs.) **(106)** Vol. 45, Pt. 2.
Fire-Damp in Coal Mines. John Harger. (Paper read before the Manchester Geological and Min. Soc.) **(106)** Vol. 45, Pt. 2.
An Address to Practical Men, Being Some Further Notes on the Combustion of Oxygen and Coal-Dust in Mines. W. C. Blackett. (Paper read before the North of England Inst. of Min. and Mech. Engrs.) **(106)** Vol. 45, Pt. 2.
The Lighting Efficiency of Safety-Lamps.* T. A. Saint. (Paper read before the North of England Inst. of Min. and Mech. Engrs.) **(106)** Vol. 45, Pt. 2.
The Electrification of Cannock Chase Colliery.* S. F. Sopwith. (Paper read before the South Staffordshire and Warwickshire Inst. of Min. Engrs.) **(106)** Vol. 45, Pt. 2.
Rearer Workings at Podmore Hall Collieries with Special Reference to Alluvium Saturated with Water. William Barber. (Paper read before the North Staffordshire Inst. of Min. and Mech. Engrs.) **(106)** Vol. 45, Pt. 2.
Underground Fires. (In Mines.)* Henry Rowan. (Paper read before the Min. Inst. of Scotland.) **(106)** Vol. 45, Pt. 2.
Timber Recovery in Square-Set Mines.* Clarence L. Larson. **(82)** May.
Mining Loads for Central Stations.* Wilfred Sykes and Graham Bright. **(42)** May.
The Hollinger Gold Mines, Ltd., Ontario.* P. A. Robbins. **(82)** May 3.
Rand Practice in Deep Shaft-Sinking. Charles B. Brodigan. **(103)** May 3.
Notes on Colliery Generating Plant.* W. Bolton Shaw. (Paper read before the Assoc. of Min. Elec. Engrs.) **(22)** May 9.
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The Rico Mining District, Colorado.* Etienne A. Ritter. **(82)** May 10.
The Principles of Mine Valuation. James R. Finlay. **(82)** May 10.
Aerial Ropeway at Bayton Colliery.* **(11)** May 16.
The Oil-Fields of Burma.* N. G. Cholmeley. **(29)** May 16.
Electric Winding at the West Rand Mines, South Africa.* **(27)** May 17.
Operation of the Tonopah Belmont Mine, Nevada.* Frederick Bradshaw. **(103)** May 17.
Bailing Through an Untimbered Shaft. Douglas Muir. **(16)** May 17.
The Production, Transmission, and Application of Power at Collieries in Scotland. W. H. Telfer. (Paper read before the National Assoc. of Colliery Managers and Assoc. of Min. Elec. Engrs.) **(22)** May 23.
Ignition of Mine Gases by the Filaments of Incandescent Lamps.* H. H. Clark and L. C. Ilsley. (From *Bulletin 52*, U. S. Bureau of Mines.) **(22)** May 23.
Compressed-Air Pit-Locomotives (for Mines). T. Giller. (Paper read before the Soc. of German Engrs.) **(57)** May 23.
The Cadeby Main Colliery Explosion.* (Report of Chf. Inspector of Mines.) **(57)** Serial beginning May 23; **(22)** May 16.
The Valuation of Mines. T. A. Rickard. (Paper read at Harvard and California Universities.) **(103)** May 24.
Fire Protection and Fire-Proofing in Mines. Herbert M. Wilson. (Paper read before the Fuel Conference, Univ. of Illinois.) **(103)** May 24; **(19)** June 28.
A Study of Riffles for Hydraulicking.* Pierre Bonery. **(16)** May 24.
Operations of the Ray Consolidated.* D. C. Jackling. **(103)** May 24.
Underground Conveying.* Sam Mavor. (Paper read before the South Wales Inst. of Engrs.) **(57)** Serial beginning May 30.
The "Briton" Automatic Water Spray for Hammer Drills.* **(22)** May 30.
Natoma No. 10, an All Steel Dredge.* Lewis H. Eddy. **(16)** May 31.
Cost of Working Thin Veins at the Standard Consolidated Mine. C. E. Grunsky, Jr. **(103)** May 31.
Recent Development at Utah Copper Company Mines. D. C. Jackling. **(103)** May 31.

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Mining—(Continued).

The Year's Improvement and Progress at Anaconda.* B. B. Thayer. (103) May 31.
Mining the Prince Consolidated Ores.* D. W. Jessup. (103) May 31.
Gas Power for Collieries.* Sydney F. Walker. (45) June.
Concrete in Mine Construction. A. F. Allard. (Paper read before the Mining Conference.) (45) June; (13) June 5.
Fire Protection of Mines. G. E. Lyman. (Paper read before the Mining Conference.) (45) June.
The Cincinnati Mine Disaster.* William Z. Price. (45) June.
Longwall Mining in Illinois.* S. M. Dalzell. (Paper read before the Mining Conference.) (45) June.
Steel in Mine Construction. Carl Scholz. (Abstract of paper read before the Interstate Mining Congress.) (62) June 2; (13) June 5.
A Study of the Cost Per Ton of Rock Mining at Eight Mines in the Joplin, Mo., District. Charles W. Burgess. (From *Colorado School of Mines Magazine*.) (86) June 4.
Active Iron Mines on Michigan Ranges.* Geo. E. Edwards. (82) June 7.
Development and Problems in the Yukon. Henry M. Payne. (82) June 7.
Works of the Seoul Mining Company, Korea.* (103) June 7.
Special American Drills for Deep Rock Cutting.* (12) June 13.
The Year at Cananea.* L. D. Ricketts. (103) June 14.
Properties of Mines Company of America. Charles Biesel. (103) June 14.
Development of Coaldust Explosions. (Report of the Explosions in Mines Committee.) (57) June 20; (22) June 20; (12) June 20.
The Measurement of Air in Mines.* Henry Louis. (Paper read before the Northumberland and Durham Assoc. of Colliery Under-Managers.) (57) June 20.
Development of the Wisconsin Zinc Field.* H. B. Pulsifer. (82) Serial beginning June 21.
Modern Steel-Tipple Design.* John A. Garcia. (Abstract of paper read before the Mining Conference at the Univ. of Ill.) (13) June 26.
Electrical Distribution for Mines. J. W. Anson. (Abstract of paper read before the South African Inst. of Elec. Engrs.) (73) June 27.
The Sulphur Industry of Sicily. Juan Blanquier. (From *Boletin* de la Sociedad Nacional de Mineria.) (68) June 28.
Uses of Steel Ties in Mining. J. Clark Evans. (Paper read before the West Virginia Mining Inst.) (62) June 30.
An Ideal Method of Mining.* J. C. Edwards and H. M. Gibb. (45) July.
A Notable Scottish Colliery.* (45) July.
Coal Mine Fires. (45) July.
Recent Experience on the Ignition of Firedamp by Electric Lamp Filaments.* Jean Mennier. (22) July 4.
New Pits of the Warwickshire Coal Company, Limited.* (22) July 11.
Framing Shaft Timber Sets by Machinery (for Mines).* Claude T. Rice. (82) July 12.
Gasoline Motors in Coal Mines. R. O. Hodges. (Abstract of paper read before the West Virginia Coal Min. Inst.) (62) July 14.
Askern Colliery.* (22) July 18.
The Magnet Silver-Lead Mine Tasmania. P. G. Tait. (Abstract from *Mining and Engineering Review*.) (103) July 19.
Tungsten in Boulder County, Colorado.* Leroy A. Palmer. (16) July 19.
The Newer Developments at Butte Mines.* Claude T. Rice. (82) Serial beginning July 19.
Traction Souterraine par Locomotives à Air Comprimé, aux Mines de Dourges (Pas-de-Calais).* (34) Serial beginning June.
L'Exploitation des Gisements Diamantiféres de l'Afrique Australe.* Jean Escard. (33) June 14.
Distribution d'Electricité et d'Air Comprimé aux Mines d'Or du Rand (Afrique Australe); Station Centrale de Rosherville.* (33) June 28.
Erzbunker aus Eisenbeton. Kupfer. (80) Apr. 26.

Miscellaneous.

The Importance of Meterological Data in Engineering. George S. Bliss. (2) Apr.
The Regulation of Public Utilities in Wisconsin. Halford Erickson. (41) May.
Rates and Rate Making. John F. Druar. (Paper read before the Civ. Engrs.' Soc. of St. Paul.) (1) May.
Note on the Construction of Thermopiles for Monochromatic Illuminators. W. W. Coblentz. (3) May.
Depreciation and Public Service Regulation. Robert H. Whitten. (13) May 8.
The Stroboscope in Speed Measurements and Other Engineering Tests.* David Robertson. (Paper read before the Inst. of Engrs. and Shipbuilders in Scotland.) (47) Serial beginning May 9.
The Engineer and His Profession. A. J. Himes, M. Am. Soc. C. E. (From the *Case Tech.*) (36) June.

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Miscellaneous—(Continued).

The Latest Development in Motion Study.* Fred H. Colvin. (72) June 5.
Recovery of Liquidated Damages; Isthmian Canal Case. William B. King. (14) June 7.
An English View of Registration of Engineers. (14) June 7.
Engineering Applications of Geology. Edwin C. Eckel. (14) Serial beginning June 14.
The Relations of the Consulting Engineer and the Municipal Engineer. H. C. H. Shenton. (Paper read before the Institution of Mun. Engrs.) (104) July 4.
Code of Ethics of the Pacific Northwest Society of Engineers. (14) July 12.
The Reflector, the Telescope of the Future.* Edward Arthur Fath. (46) July 12.
Safety Engineering.* G. Gilmour. (From *The Travelers Standard.*) (19) July 19.
State Official Coöperation to Secure Proper Valuation Under Act of Congress, Mar. 1, 1913. D. F. Jurgensen. (Paper read before the Civil Engrs. Soc. of St. Paul.) (1) July.

Municipal.

The County Roads Act of Victoria, Australia. (104) Apr. 25.
Natural and Artificial Bitumens. (104) Apr. 25.
The Planning of City Streets.* B. Antrim Haldeman. (58) May.
Congestion of Traffic on Fifth Avenue, New York. (60) May.
Pavements in Peoria, Illinois.* J. B. Jeffries. (60) May.
Cost of Asphalt Repairs.* (60) May.
Limitations of Bituminous Carpet Surfaces. A. W. Dean. (Paper read before the Am. Assoc. for the Advancement of Science.) (96) May 1.
Costs of Concrete Pavements. C. M. Boynton. (Paper read before the Am. Soc. of Engrs. and Contractors.) (96) May 1.
Highway Maintenance Costs in Foreign Countries. (86) May 7.
Instruction for Building State Aid Roads in Wisconsin. (*Bulletin*, Wisconsin Highway Comm.) (86) May 7.
The Specifications of the Illinois Highway Commission for Concrete Road Construction. (86) May 7.
Municipal Work in Newcastle-upon-Tyne. W. J. Steele, M. Inst., C. E. (Paper read before the Institution of Mun. and County Engrs.) (104) Serial beginning May 9.
Scientific City Planning. Geo. B. Ford. (Paper read before the Fifth National Conference on City Planning.) (86) May 14.
Maintenance of Sheet Asphalt Pavements. Francis P. Smith. (96) May 15.
Method and Cost of Asphaltic Macadam Construction on the Boulevard System of Kansas City, Mo.* C. W. Redpath. (86) May 21.
Superelevation at Bends on Roads. Reginald Ryves, Assoc. M. Inst. C. E. (104) May 23.
Oiled Macadam for Residence Streets in San Bernardino.* (14) May 24.
Bituminous Macadam Construction by the Illinois Highway Commission.* (86) Serial beginning May 28; (96) June 26.
Highway Construction with Paint Binder and Its Sheet Asphalt Surface. A. E. Loder. (Abstract from *Bulletin*, California Highway Comm.) (86) May 28.
General Instructions to Inspectors of Street Paving (Borough of Manhattan, New York City). (13) May 29.
Improving Desert Roads for Motor-Truck Haulage. (13) May 29.
By-Pass Roads, the Principles Which Should Govern Their Alignment and Construction. Reginald Ryves, Assoc. M. Inst. C. E. (104) May 30.
Asphaltic Concrete as a Paving Material for Residence Streets, Suburban Districts and Boulevards. Linn White. (Paper read before the Civ. Engrs. Soc. of St. Paul.) (1) June.
How to Obtain Best Results from Wood Block Pavements. H. L. Collier. (60) June.
Concrete Pavement Failures.* (60) June.
A Five-Storied Street, an Effective and Practical Plan for Handling the Congested Traffic in Great Cities.* Henry Harrison Suplee. (10) June.
Experimental Road Work of the Public Roads Department of New Jersey. (86) June 4.
Work of the Efficiency Division, Chicago Civil Service Commission. (14) June 7.
Work of the Philadelphia Bureau of Highways.* (14) June 7.
Maintenance of Country Roads in Dundee District. James B. Robertson. (Paper read before the Institution of Municipal and County Engrs.) (104) June 13.
Road Making Development. (104) June 13.
Rating the Efficiency of Municipal Employees. (14) June 14.
Sand-Clay Road Construction in Butler County, Alabama. Geo. C. Scales. (Abstract of paper read before the Alabama Assoc. of Highway Engrs.) (86) June 18.
Road Management. Laurence I. Hewes. (From *Bulletin*, U. S. Office of Public Roads.) (86) June 18.
The Land Tax Method of Raising Funds for the Park and Boulevard System of Kansas City, Mo. George E. Kessler. (Paper read before the National Conference on City Planning.) (86) June 18.

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Municipal—(Continued).

Tar-Spraying and Tar-Macadam in Situ. Thomas Aitken, M. Inst. C. E. (104) Serial beginning June 20.
Specifications of the Board of Local Improvements, Chicago, Ill., for Concrete Pavements. (86) June 25.
The Trend of Modern Road Construction. R. E. Crompton and H. Percy Boulnois. (Paper read before the Roads Improvement Assoc.) (104) June 27.
Inefficiency in Highway Construction. (14) June 28.
Chevy Chase Experimental Concrete Road: Bituminous, Oil-Cement and Plain Cement Concrete Highway Pavement.* (14) June 28.
St. Louis Plans a Central Traffic Parkway.* (60) July.
The Brick Road the Cheapest and Most Economical. (60) July.
Concrete Pavement Construction.* (60) July.
Sidewalk Construction (Specifications for Cement Walks). (67) July.
Wood Block Pavements (with Specifications). Geo. W. Tillson. (86) July 2; (96) July 24.
The Scientific Selection of Pavements. W. W. Crosby, M. Am. Soc. C. E. (96) July 3.
Conclusions Regarding Macadam Road Construction. (96) July 3.
Leek and Its Municipal Works.* W. E. Beacham. (Paper read before the Institution of Mun. and County Engrs.) (104) Serial beginning July 4.
Concrete Pavements and Correct Methods of Their Construction.* Morse-Warren Eng. Co. (86) July 9.
Convict Labor in Highway Construction. Joseph Hyde Pratt. (Paper read before the Third Inter. Road Congress.) (86) July 9.
Central Road Authorities. Paul D. Sargent. (Paper read before the Third Inter. Road Congress.) (86) July 9.
Macadamized Roads Constructed with Tarry, Bituminous or Asphaltic Binders. A. H. Blanchard. (Abstract of paper read before the Third Inter. Road Congress.) (96) July 10.
Why Some Municipal Asphalt Plants Fail. H. B. Pullar, Assoc. M. Am. Soc. C. E. (96) July 10.
Wire-Cut Lug Paving Blocks.* F. B. Marsh. (14) July 12.
Reinforced Concrete Paving at Port Huron, Mich.* Earle R. Whitmore. (86) July 16.
Observations Noted Since 1908 as to the Various Causes of Wear and Deterioration of Roadway. L. I. Hewes. (Paper read before the Third Inter. Road Congress.) (86) July 16.
The Penetration Method in Macadam Road Construction. W. W. Crosby. (Abstract of paper read before the Third Inter. Road Congress.) (96) July 17.
Road Resolutions Adopted by the 1913 Congress. (96) July 17.
Plain Concrete Paving Used in Kansas City, Mo.* Clark R. Mandigo. (13) July 17.
Transportation and City Planning. Milo R. Maltbie. (14) July 19.
Piecework System in Philippine Road Construction. (14) July 19.
Constituent Principles of Highway Maintenance. (14) July 19.
Expansion and Contraction Measurement of Concrete Roadways.* A. T. Goldbeck. (14) July 19.
Supplementary Reports on the 1907, 1908, 1909, 1910 and 1911 Dust Prevention and Road Preservation Experimental Work of the U. S. Office of Public Roads. (86) July 23.
Surface Treatment and Bituminous Macadam Construction with High Pressure Spraying Machines. Thomas Aitken. (Paper read before the Third Inter. Road Congress.) (86) July 23.
Some Notes on Macadam Roads and Pavements. Fred L. Macpherson, A. M. Inst. C. E. (96) July 24.
The Third International Road Congress at London. E. L. Corthell. (13) July 24.
Le III^{e} Congrès International de la Route, Londres, 23-28 Juin, 1913. A. Dumas. (33) July 12.
Das Automobil im Dienste der modernen Stadtverwaltung.* Leopold Merz. (39) Apr. 5.
Bauordnung für Mannheim. Ehlgötz. (39) Serial beginning Apr. 20.
Strassenbau im Südlichen Belgien.* Eduard Schneider. (39) May 20.
Die Geschichte des Walzasphaltpflasters in der Fünften Avenue in New York. Erwin Neumann. (39) May 20.
Fundierung der Siemenstrasse in Berlin-Oberschöneweide.* J. Th. Hamacher. (39) June 5.
Die Hofzufahrt und das öffentliche Interesse.* H. Steinberger. (39) June 5.
Einheitliche Strassenbordsteine.* D. Scheuermann. (39) June 5.

Railroads.

Characteristic Dynamical Diagrams for the Motion of a Train During the Accelerating and Retarding Periods.* W. E. Dalby. (75) Oct., 1912.
The Mechanics of Electric Train Movement. F. W. Carter. (77) Apr.
The Derailments of Tank Engines.* (23) Apr. 18.
The London and Northwestern Railway Works, Crewe.* (23) Apr. 18.

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Railroads—(Continued).

Three Recent Railway Accidents.* (12) Apr. 25.
Overhead Equipment for Single-Phase Railways.* (12) Apr. 25.
Modern Locomotive Practice in Europe and America. Lawford H. Fry. (Paper read before the Institution of Locomotive Engrs.) (47) Apr. 25.
Great Western Railway Goods Depot at South Lambeth, London.* (23) Apr. 25.
Heavy Passenger and Goods Engine; Northern Railway of France.* (21) May.
The Introduction of Compound Goods Locomotives in Bavaria, and Its Objects.* (21) Serial beginning May.
20-Ton Four-Wheel Plate Wagon; North Eastern Railway.* (21) May; (23) June 13.
Trials of the "Clayton-Hardy" Rapid Acting Vacuum Brake for Goods Trains; Austrian State Railways.* (21) May.
Firing up Locomotives. C. E. Lester. (94) May.
The Administration of the State Railways of Prussia-Hesse. William J. Cunningham. (65) May.
Automatic Block Signals, C., M. and St. P. Ry., Puget Sound Lines.* B. W. Meisel. (87) May.
Protecting Against and Repairing Washouts.* J. W. Powers. (87) May.
Service Tests of Ties, Progress Report. (From *Bulletin,* U. S. Forest Service.) (87) May.
2 400-Volt Railway Electrification. H. M. Hobart. (42) May.
Trunk Line Electrification.* Chas. P. Kahler. (42) May.
The Hauling Capacity of Locomotives. H. D. Cameron. (Paper read before the Western Canada Railway Club.) (96) May 1.
Locomotive and Train Acceleration.* Lawford H. Fry. (12) Serial beginning May 2.
Four-Cylinder Prairie Type Express Locomotive; Italian State Railways.* Ernesto Breda. (12) May 2.
New Locomotive Sheds, Italian State Railways.* L. Greppi and F. Rolla. (From *Rivista Tecnica delle Ferrovie Italiane.*) (23) May 2.
The Erimus Hump Yard, Middlesbrough, North-Eastern Railway.* (23) May 2.
New Locomotive for the Antofagasta Railway.* (23) May 2.
Notes on Midi D. C. and A. C. Electrifications.* (17) May 3.
Electrification of British Railways.* (17) May 3.
Pacific and Mikado Locomotives for the Denver & Rio Grande R. R.* (18) May 3.
Freight Terminals and Freight Handling at Terminals.* J. S. Busfield. (96) Serial beginning May 8.
The Case of the Chilled Cast Iron Car Wheel.* George W. Lyndon. (20) May 8.
Track Elevation at Joliet, Ill.* (13) May 8.
Mallets on the Norfolk & Western. (15) May 9; (18) June 14.
New Superheater Locomotives; Great Northern Railway (Ireland).* (23) May 9.
2-8-0 Type Locomotive, South Indian Railway.* (23) May 9.
Four-Cylinder Express Locomotive, 4-6-0 Type, London & North Western Railway.* (23) May 9.
General Manager's Saloon, Central Argentine Railway.* (23) May 9.
Double Tracking on the Nashville, Chattanooga & St. Louis.* (15) May 9.
Construction of the Portland, Eugene & Eastern Ry.* Mark Woodruff. (18) May 10.
Mikado Locomotives for the Lake Shore & Michigan Southern Ry.* (18) May 10.
Chicago Terminals and the Smoke Problem. R. E. Pierce. (Paper read at Cornell University.) (18) May 10.
New Type of Rail Joint for Bascule and Vertical Lift Bridges.* (18) May 10; (86) May 28.
Starting, Running and Stopping Long Freight Trains. F. B. Farmer. (Abstract of paper read before the Air Brake Assoc.) (18) May 10; (15) May 9.
Smoke-Washers for Roundhouses.* (13) May 15.
Slide Valve Successfully Used on Superheater Locomotives. (15) May 16.
Will the Triple Valve Operate as Intended? S. W. Dudley. (Paper read before the Air Brake Assoc.) (15) May 16; (25) June.
Railways of the Union of South Africa. E. R. Lewis. (15) May 16.
Car Wheels. A. A. Hale and M. D. Hayes. (Papers read before the New England Railroad Club.) (15) May 16.
Santa Fe Roundhouse at Riverbank, Cal.* (15) May 16.
Comparative Economy of Treated Ties. R. J. Parker. (15) May 16.
Guard Rail Design.* F. W. Rizer. (15) May 16.
Pressure-Balanced Piston Rings.* (12) May 16.
New Engine Programme of the South African Railways. (23) May 16.
Pressed Steel Underframes with Four-Wheeled and Six-Wheeled Bogies.* (23) May 16.
Corrosion of Locomotive Boilers.* (23) May 16.
The Last Broad-Gauge Railway and Locomotive.* Alfred R. Bennett. (23) May 16.
Express Passenger Locomotive, Paris-Lyons-Mediterranean Railway.* (11) May 16.
The Lötschberg or Bernese Alpine Railway.* Alfred Gradenwitz. (46) May 17; (19) May 17.

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Railroads—(**Continued**).

Electrification of Chicago Railway Terminals.* (18) May 17.
Preliminary Railway Surveying by Means of the Stadia.* J. A. Macdonald. (96) May 22.
Length of Crossover between Curved Parallel Tracks.* R. W. Stewart. (13) May 22.
New Kansas City, Mo., Passenger Terminal.* (15) May 23.
The Problem of Railway Valuation. Logan G. McPherson. (Paper read before the Am. Assoc. of Freight Traffic Officers.) (15) May 23.
Mounting of Radial Couplers. A. L. Price. (Abstract of paper read before the Central Elec. Ry. Assoc.; from *Electric Railway Journal.*) (73) May 23.
Railway Water Troughs. (23) Serial beginning May 23.
Grand Trunk Terminal, Ottawa.* (23) May 23.
Light Railway Construction in Egypt.* (23) May 23.
Interior Finishing of All-Steel Coaches.* (23) May 23.
Effect of Stores Department on Operating Cost. H. C. Pearce. (Paper read before the Ry. Storekeepers' Assoc.) (15) May 23; (18) May 24.
Standard Supply Car.* D. D. Cain and L. O. Genest. (Papers read before the Ry. Storekeepers' Assoc.) (15) May 23.
Track Elevation of the P. R. R. at Pittsburgh.* (18) May 24.
New Union Station for Chicago.* (18) May 24; (15) May 23.
Railway Capitalization. Slason Thompson. (18) May 24.
A 40-Ton Electric Locomotive.* (17) May 24.
Spiral for Railway Curves.* Erwin Davis. (14) May 24.
The Design and Operation of the New Timber Treating Plant of the Baltimore and Ohio Railroad.* F. J. Angier. (86) May 28; (18) May 17; (13) June 5; (15) June 20; (87) June.
Canadian Pacific Railway Shops at Ogden, Alberta.* (96) May 29.
A Locomotive with the Stumpf Direct-Flow System of Steam Distribution.* (13) May 29.
Studies in Operation, the M. K. and T.* (15) May 30.
Canadian Pacific Coal Unloading Dock.* (15) May 30.
Compressed-Air Pit Locomotives. Butow and Dobbelstein. (From *Glückauf.*) (22) May 30.
The Grand Central Railway Station, New York.* (11) May 30.
High-Capacity Freight Rolling Stock, Caledonian Railway.* (22) May 30.
Heavy 2-8-2 Tank Locomotive for the Bengal Nagpur Railway.* (23) May 30.
Self-Propelled Cars.* S. T. Dodd and B. H. Arnold. (Paper read before the Inter. Ry. Fuel Assoc.) (15) May 30; (18) June 7; (23) July 18; (25) June.
Relocating of Chicago Railway Terminals.* (15) May 30.
Terminal Station Plans of the Mississippi North-Western R. R. at Pascagoula, Miss.* (18) May 31.
Vast Public Interests Involved in Rate Questions. Slason Thompson. (18) May 31.
A New Port and Railroad Terminal on the Gulf, Freeport, Tex.* A. W. Davis. (18) May 31.
A British Gasoline-Electric Motor Car.* (18) May 31.
The Car Roof Problem. (18) Serial beginning May 31.
The Effect of a Well Organized Store Department on the Operating Cost of a Railroad. N. M. Rice. (Paper read before the Ry. Storekeepers' Assoc.) (18) May 31; (19) June 14.
Elimination of Smoke. D. F. Crawford. (Paper read before the New Century Club.) (18) May 31; (62) June 16.
Utica General Improvement on the New York Central & Hudson River Railroad.* (14) May 31.
Undesired Quick Action of Brakes. C. N. Remfry. (Paper read before the Air Brake Assoc.) (25) June.
Safety Devices for Locomotive Boilers.* (25) June.
Railroading Without Steam.* Don Cameron Shafer. (10) June.
Inspection of Locomotive Boilers. John F. Ensign. (108) June.
A General Description of the Delaware, Lackawanna & Western Railroad Cut-off in New Jersey.* Arthur L. Willgoose. (36) June.
A Saxon Engineering Works.* Charles R. King. (9) Serial beginning June.
Concrete in Railroad Work. M. A. Long. (Abstract of paper read before the National Assoc. of Cement Users.) (87) June.
Electro-Pneumatic Interlocking at Montclair, N. J., D. L. & W. R. R.* B. W. Meisel. (87) June.
New English Wireless Railophone.* (87) June.
Four-Cylinder 4-6-0 Passenger Engines "Claughton" Class, L. & North Western Railway.* (21) June.
Overturning on Railway Curves. (21) June.
Pacific Type Locomotives; New York, New Haven and Hartford R. R. (21) June.
Design of a Concrete Retaining Wall with Foundations on Permeable Soil.* E. E. Howard. (87) June.

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Railroads—(Continued).

Three Level Crossing at 75th Street, Chicago.* (87) June.
Some Features of Double-Track Railroad Construction on the Chicago, Milwaukee and St. Paul Railway in South Dakota.* F. W. Van Buskirk. (86) June 4.
The Westchester Railway Lines and Structures.* (13) Serial beginning June 5.
Grand Trunk Grade Separation in Toronto.* (15) June 6.
Combustion in Locomotive Practice.* J. T. Anthony. (15) June 6.
Why Freight Rates Should Be Increased. Daniel Willard. (From Phila. *Public Ledger.*) (15) June 6; (18) May 31.
The Automatic Train Stop Problem. A. H. Rudd. (Abstract from *The Signal Engineer.*) (15) June 6.
The Prussian-Hessian State Railways. W. J. Cunningham. (23) June 6.
Seventy-fifth Anniversary of the Great Western.* (23) June 6.
Articulated Electric Locomotives; New York Central Railway.* (23) June 6.
The New Multiple-Unit Rolling Stock of the Ouest-Etat Railway.* (73) June 6.
A New Dynamo for Train Lighting.* (12) June 6.
An Italian 1 300 Volt D. C. Railway.* (17) June 7.
Single-Phase Railway Motors.* Louis Bell. (17) June 7.
Electrification Progress in the United States.* (17) June 7.
Locomotives for the Butte, Anaconda & Pacific.* (17) June 7; (18) June 14; (105) July; (13) June 26.
Electric Railway Track Work. Victor Angerer. (Paper read before the Keystone Railway Club.) (17) June 7.
Pacific Type Locomotives for the Erie Railroad.* (18) June 7.
Vanadium Cast-Steel Locomotive Frames.* (18) June 7.
Maintenance on the Electrified Section of the Erie Railroad.* (17) June 7.
The Screw Spike Versus the Cut Spike.* (46) June 7.
Safety in Travel as Affected by the Steel Rail.* (46) June 7.
Railroad Tie Renewals.* (14) June 7.
Direct-Current 2 400-Volt Locomotives.* (27) June 7; (15) June 13.
Locomotive Terminals and Repair Facilities of the Northern Pacific Ry. in the State of Washington.* (18) June 7.
Radical Departure Proposed in Railway Branch Line Service. Francis E. Drake. (18) June 7.
Mikado Type Locomotive, Philadelphia & Reading Ry.* (18) June 7.
The Storage Battery Car in Branch Line Service.* J. H. Tracy. (Abstract of paper read before the Inter. Ry. Fuel Assoc.) (18) June 7.
State Railway Commissioners and Federal Valuation. D. F. Jurgensen. (Paper read before the Mississippi Valley States Conference on Railroad Valuation.) (18) June 7.
Mechanical Stokers. W. C. Hayes. (Paper read before the Master Mechanics' Assoc.) (15) June 12.
4-6-2 Type Locomotive for the New Haven.* (15) June 12.
Mechanical Stokers from Operating Standpoint.* (15) June 13.
New Extension of the Norfolk Southern.* (15) June 13.
Thirty-Mile Electrification on Norfolk & Western. (15) June 13.
New Yards of the Chicago & Alton Near Chicago.* (15) June 13.
The Progress of Three-Phase Traction on Railways. (26) June 13.
Some Continental Train Improvements. (12) June 13.
The Oldest Engine on the Northern of France Railway.* (23) June 13.
Grand Trunk Mikados.* (15) June 13.
Maintenance of Locomotive Boilers.* (Report of Committee of the Master Mechanics' Assoc.) (15) June 13.
Specifications for Cast-Steel Locomotive Frames. Master Mechanics' Assoc. (15) June 13.
Maintenance of Electric Equipment (for Railroads.) C. H. Querean. (Paper read before the Master Mechanics' Assoc.) (15) June 13; (13) July 3.
The Oregon Electric Railway.* (17) June 14.
Electric Railway Costs. John B. Sparks. (17) June 14.
Final Testimony and Arguments in the Cleveland Case. (17) June 14.
Steel Passenger Equipment Cars, Norfolk & Western Ry.* (18) June 14.
Specifications for Materials Used in Locomotive Construction. (Report of Committee, Master Mechanics' Assoc.) (15) June 14.
Superheater Locomotives. (Report of Committee, Master Mechanics' Assoc.) (15) June 14.
Special Alloys and Heat-Treated Steel in Locomotive Construction. (Report of Committee, Master Mechanics' Assoc.) (15) June 14.
Smoke Prevention.* (Report of Committee, Master Mechanics' Assoc.) (15) June 14.
Engine and Tender Wheels.* (Report of Committee, Master Mechanics' Assoc.) (15) June 14.
Tests of Superheater Locomotives.* C. H. Benjamin and L. E. Endsley. (Paper read before the Master Mechanics' Assoc.) (15) June 14; (18) July 5.
4-6-2 Type Freight Locomotive.* (15) June 14.
Powerful Pacifics for the Erie. (15) June 14.

*Illustrated.

Railroads—(Continued).

Modern Air Brake Equipment as Applied to Steam Roads. Charles V. Joy. (Abstract of paper read before the New England R. R. Club.) (18) June 14.
Terminal Service. W. M. Prall. (Abstract of paper read before the Ry. Club of Pittsburgh.) (18) June 14.
Canadian Pacific Railway Shops at Ogden.* (14) June 14.
Construction Work on a Short Railroad Branch: Building Bridge Piers in Shallow Water, Cofferdams, Erecting Long Girders with Derrick Car, and Making Fill from Movable Trestle (Central R. R. of New Jersey).* (14) June 14.
Mikados for the Lehigh Valley.* (15) June 16.
Steel Postal Car.* (15) June 16.
Train Brake and Signal Equipment. (Report of Committee, Master Car Builders' Assoc.) (15) June 17.
Brake Shoe and Brake Equipment. (Report of Committee, Master Car Builders' Assoc.) (15) June 17.
Coupler and Draft Equipment.* (Report of Committee, Master Car Builders' Assoc.) (15) June 17.
Car Wheels.* (Report of Committee, Master Car Builders' Assoc.) (15) June 17.
Revision of the Rules of Interchange. (Report of Committee, Master Car Builders' Assoc.) (15) June 17.
Variable Load Brake.* (15) June 17.
Revision of Standards and Recommended Practice. (Report of Committee, Master Car Builders' Assoc.) (15) June 17.
Car Trucks.* (Report of the Committee on Car Trucks of the Master Car Builders' Assoc.) (15) June 18.
Train Pipe and Connections for Steam Heat.* (Report of Committee, Master Car Builders' Assoc.) (15) June 18.
Method of Constructing a High Retaining Wall in Trench in a Narrow Side Hill Space.* C. S. L. Hertzberg. (Abstract from *Applied Science*.) (86) June 18.
Air Brake Hose Specification.* (Report of Committee, Master Car Builders' Assoc.) (15) June 19.
Car Construction.* D. F. Crawford. (Abstract of paper read before the Master Car Builders' Assoc.) (15) June 19.
Coke and Iron Ore Freight Rate Decision. (20) June 19.
The Supreme Court's Comments on Valuation. (15) June 20.
Tunnel Lining on the Virginian Railway.* (15) June 20.
Arlberg Railway Electrification Scheme.* (23) June 20.
Petrol Rail Motor Cars for the Queensland Government Railways.* (23) June 20.
Continental Engine Sheds.* Henry W. Jacobs. (23) June 20.
A Locomotive Valve Gear.* C. F. Dendy Marshall. (12) June 20.
New Locomotives for the Denver and Rio Grande Railroad.* (12) June 20.
Possibilities of Increasing Profits on Interurban Tramways. E. H. Edwards. (Abstract of paper read before the Tramways and Light Railways Assoc.) (73) June 20.
Railway Evaluation and Depreciation; Views of U. S. Supreme Court Expressed in the Minnesota Rate Case Decision. (14) June 21; (18) June 14.
Three-Cylinder Locomotives.* J. Snowden Bell. (Abstract of paper read before the Am. Ry. Master Mechanics Assoc.) (18) June 21; (15) June 14; (47) July 18.
Special Equipment on the Bloomingdale Road Track Elevation.* (14) June 21.
Pacific Type Locomotives for the Nashville, Chattanooga and St. Louis Ry.* (18) June 21.
New Shops for the Canadian Pacific Railway near Calgary, Alberta, Canada.* (13) June 26.
Steel Ties on Foreign Railways.* (13) June 26.
A Special Problem in Reverse Curves.* Wm. C. Crosby. (13) June 26.
Illinois Central Mechanical Terminal.* (15) June 27.
The New Works of Messrs. Nasmyth, Wilson and Co., Ltd., Patricroft, Manchester.* (23) June 27.
Comparative Fire-Box Tests.* (23) June 27.
Something Along the Line of Physical and Intangible Valuation as Covered by Recent Legislation. Robert B. Rifenberick. (Paper read before the Central Elec. Ry. Assoc.) (17) June 28.
Weed Burner in Los Angeles (Pacific Electric Railway).* (17) June 28.
Gasolene Freight and Switching Locomotive.* (17) June 28.
Mt. Royal Tunnel, Canadian Northern Railway.* S. P. Brown. (14) June 28.
Reconstruction of Chicago Clearing Yard (Chicago and Western Indiana R. R.).* (14) June 28.
Manufacture of Switches and Frogs.* (18) Serial beginning June 28.
Construction of the Lewistown-Great Falls Line of the C., M. and St. P. Ry.* (18) Serial beginning June 28.
Trailing Axle-Box for 4-4-2 Engine; Hungarian State Railways.* (21) July.
Railway Construction in Patagonia. (21) July.
Dynamometer Performance of Saturated and Superheated Steam Locomotives. (21) Serial beginning July.

*Illustrated.

Railroads—(Continued).

Schleyder's Blast Pipe.* (21) July.
Underframe for 70 Ft. Coaching Stock; Great Western Railway.* (21) July.
Concrete Practice, National Railways of Mexico.* A. M. Wolf. (87) July.
Electric Interlocking at Aliquippa, Pa.* B. W. Meisel. (87) July.
Mechanical Terminal for Illinois Central.* Willard Doud. (25) July.
Gaines Firebox on the Illinois Central.* (25) July.
Making Stock Cars from Scrapped Box Cars. Wm. Queenan. (25) July.
Method of Designing a Steel Gondola Car.* L. W. Wallace. (25) July.
Special 75-Ton Flat Car, Erie R. R.* R. S. Mounce. (25) July.
Wasting a Million a Day (by Railroads).* M. Gesundheit. (10) July.
Flood Destruction on the San Pedro Railway.* H. G. Tyrrell. (13) July 3.
Track Elevation and Portable Concreting Plant, C. M. & St. P. Ry.* (13) July 3.
The Strength of Steel Cars. (Abstract of Report of the Committee on Car Construction of the Master Car Builders' Assoc.) (13) July 3.
New Montclair Station of the Delaware, Lackawanna & Western.* (15) July 4; (18) July 12.
Powdered Fuel for Locomotives. Walter D. Wood. (15) July 4.
The St. Paul Improvements at Milwaukee.* (15) July 4.
Assignment of Equipment Valuation by States. A. I. Thompson. (15) July 4.
The Possibilities of Motor Vehicles for Railway Purposes from the Operator's Standpoint. J. Pepper. (23) July 4.
The Railway Conquest of the Alps from the Semmering to the Loetschberg Tunnel.* (23) July 4.
The Loetschberg Tunnel.* (12) July 4.
Pacific Type Locomotives (Delaware, Lackawanna & Western R. R.).* (18) July 5.
Locomotive Boiler Inspection.* Garland P. Robinson. (Paper read before the Interstate Commerce Comm.) (18) July 5.
The Hubbard Automatic Switch Point Closer or Lock.* (18) July 5.
The Mittenwald Railway.* E. E. Seefehlner. (From *A. E. G. Journal.*) (17) July 5.
The Montreal Tunnel and Terminal.* S. P. Brown. (13) July 10.
The Canadian Northern Ry.* Henry K. Wicksteed. (13) July 10.
Tests of Alcohol Heater Car.* (15) July 11.
The Minimum Efficient Gradient.* Paul M. La Bach. (15) July 11.
Railroad Cost and Efficiency. (15) July 11.
Turntable Tractor.* (15) July 11.
Oil-Fuel on the Austrian State Railways.* (23) July 11.
Track Circuits in India.* (23) July 11.
Train Control. (12) Serial beginning July 11.
Proposed Plan for One Central Railway Terminal for Chicago.* R. C. Sattley. (18) July 12.
Motor Generators and Frequency in Alternating Current Railway Signaling. J. E. Saunders. (Papers read before the Ry. Signal Assoc.) (18) July 12.
Tree Windbreaks to Replace Portable Snow Fences.* (14) July 12.
High-Voltage Direct-Current Locomotives.* (103) July 12.
Grade-Crossing Elimination at Second Avenue and Try Street, Pittsburgh.* (14) July 12.
Construction Work on the Idaho Northern Ry.* J. H. Smith. (13) July 17.
Studies of Operation; the C. B. and Q.* (15) July 18.
Life of Locomotive Fireboxes.* C. T. Rommel. (15) July 18.
Report on Stamford Collision. (Report of the Interstate Commerce Comm.) (15) July 18; (18) July 19.
Motor Cars for Maintenance of Way Forces. (15) July 18.
The Standard Track Scale of the P. and L. E.* (15) July 18.
Baltimore and Ohio Flood Reconstruction.* (15) July 18.
Chesapeake and Ohio Yard at Silver Grove, Kentucky.* (15) July 18.
Power Signalling on the Great Central Railway.* J. A. Jenkinson and Charles Travis. (23) July 18.
New Goods Engines, G. N. of I. Railway.* (23) July 18.
Hasler Locomotive Speed Indicator and Recorder.* (23) July 18
Power-Generating Equipment on the Cleveland, Painesville and Eastern Railroad.* (17) July 19.
New 40-Mile Extension of the Waterloo, Cedar Falls and Northern Railway.* (17) July 19.
Notes on the Design and Operation Costs of Modern Locomotive Coaling Stations. (Report of Committee of the Inter. Ry. Fuel Assoc.) (86) July 23.
New Railway Stations and Six-Track Tunnels at Brussels (Belgium.) (13) July 24.
The Question of Increased Freight Rates. A. B. Hulit. (15) July 25.
Extensive Improvements on the L. & N.* (15) July 25.
A Day's Train Record Over Tehachapi Mountain.* (15) July 25.
The Railways of Peru.* O. Sperber. (18) July 26.
Mallet Compound Locomotive for the Pennsylvania R. R.* (18) July 26.
Progress in the Mount Royal Railroad Tunnel.* Howell T. Fisher. (16) July 26.

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Railroads—(Continued).

Relocation and Grade Reduction on the Louisville & Nashville Railroad.* (14) July 26.
Chemins de Fer d'Intérêt Local et Tramways à Vapeur pour le Service des Voyageurs et des Marchandises. P. Dumas. (43) Mar.
Le Locotracteur Schneider & Cie. (Locomotive à Hydrocarbure.) E. Brillié. (32) Apr.
La Nouvelle Gare Centrale Terminus de New York.* P. Calfas. (33) May 10.
Comparison entre les Systèmes de Traction in Concurrence pour l'Electrification des Grandes Lignes. E. de Marchena. (33) May 17.
Les Locomotives de la Compagnie P. L. M. à l'Exposition de Gand.* L. Pierre-Guédon. (33) Serial beginning May 24.
Locomotive Schneider & Cie, de 70 Chevaux, à Moteur à Explosion et Transmission Aërothermique, Système Hautier.* L. Pierre-Guédon. (33) May 31.
Le Funiculaire Aérien à Voyageurs de Larra au Vigiljoch (Tyrol).* (33) June 7.
L'Attelage Automatique des Wagons par l'Auto-Coupleur Boirault.* G. Espitallier. (33) June 14.
Les Locomotives Britanniques en 1912; Types et Services.* L. Pierre-Guédon. (33) June 21.
Note sur la Réparation des Cylindres de Locomotives.* Bonnin. (38) July.
Das Entwerfen und der Bau der Eisenbahn-Empfangsgebäude.* Cornelius. (49) Serial beginning Pt. 4.
Ueber die Entstehung der Risse in der Rohrwand von Lokomobil und ähnlichen Kesseln.* C. Bach. (48) Mar. 22.
Das Trocknen des Kesseldampfes.* C. Guillery. (102) Apr. 15.
Das Stuttgarter Bahnhofsgelände einst jetzt und künftig.* H. Werner. (39) Apr. 20.
Oberleitungslokomotiven für Werkbahnen.* F. Riep. (41) Serial beginning Apr. 24.
Speisewasservorwärmung bei Lokomotiven.* Ludwig Schneider. (48) Serial beginning May 3.
Das Verdampfungsgesetz des Lokomotivkessels.* O. Köchy. (102) Serial beginning May 15.
Anlage zur Bekohlung der Lokomotiven im Bahnhofe Kempten i. Allg. Bisle. (102) May 15.
Anlage zur Ueberführung von Leichen bei Bahnhof Berlin-Halensee.* Lücking. (40) May 21.
Gleisabzweigung aus gekrümmter zweigleisiger Hauptbahnstrecke.* (40) May 21.
Die neue Lokomotiv-Remise der S. B. B. auf dem Aebigut in Bern.* (107) May 31.
Schaulinien der Dampfverteilung bei Verbundlokomotiven.* O. Kölsch. (102) Serial beginning June 1.
Die Eisenbahnen in Makedonien und Thrakien und die bulgarischen Bauprojekte.* Franz Manek. (53) June 13.
Bedingungen für die Lieferung von Stahlschienen, Neuyork-Zentralbahn. (102) June 15.
Ueber den Reibungswiderstand zwischen Schiene und Lasche in den Anlageflächen. E. C. W. van Dyk. (102) June 15.
Versuche mit Eisenbetonschwellen und die Asbeston-Schwelle von R. Wolle. (102) July 1.
Die Ursache der Riffelbildung an Schienen.* F. Märtens. (50) July 10.

Railroads, Street.

The Pittsburgh Subway Problem. William Glyde Wilkins. (58) May.
Trackless Trolley Lines in Austria.* Frank C. Perkins. (60) May.
Fly-Over Junction on the Metropolitan District Railway at Earl's Court.* (11) May 2.
New Substations in Buffalo.* (17) May 10.
Final Report on San Francisco.* (Transportation Conditions.) B. J. Arnold. (Report to the Board of Supervisors.) (17) May 10.
Newcastle-upon-Tyne Tramways Extensions. J. McKellar. (Paper read before the Inst. of Mun. and County Engrs.) (104) May 16.
Sydney City and Suburban Railways.* (11) May 16.
Electric-Arc Welding and Other Features of the San Francisco Shops.* (17) May 17.
Track Improvement in Cleveland.* (17) May 17.
Appraisal of the City Lines of the Detroit United Railway.* (17) May 17.
Derrick Cars and Wrecking Cranes for Electric Railways.* (13) May 22.
Illinois Traction System's Freight House at Springfield, Ill.* (17) May 24.
Analysis of the Premises Adopted and Methods Used in Determining the Cost to Reproduce New, Together with the Depreciation Thereon of the Physical Property of the Metropolitan System and the Kansas City and Westport Belt Railway of Kansas City, Mo. Bion J. Arnold. (86) May 28; (13) May 22.
Petrol-Electric Tramcars for the London County Council.* (12) May 30; (17) July 5.

*Illustrated.

Railroads, Street—(Continued).

New Double-Deck Cars for Pittsburgh.* (17) May 31.
Recent Passenger Stations in Los Angeles.* (17) May 31.
Report on Toronto Conditions. Bion J. Arnold. (Report to Corporation Counsel of the City of Toronto.) (17) May 31.
Self-Propelled Tramway Cars. (104) June 6.
Difficult Bracing for Subway. (14) June 7.
The Lot's-Road Station of the Underground Electric Railways, London. (73) June 13.
Stress Analysis of Circular Tubes; Analytical and Graphical Determinations of Stresses in Tunnel Sections Under Various Conditions of Loading.* Björgulf Haukelid. (14) June 14.
Tramway Track, 1883 to 1913. F. Bland. (Abstract of paper read before the Tramways and Light Rys. Assoc.) (73) June 20.
Rail-Less Traction Legislation. H. England. (Abstract of paper read before the Tramways and Light Rys. Assoc.) (73) June 20.
Improvements to a Cable Road in Seattle.* (17) June 21.
Luzerne Carhouse of the Philadelphia Rapid Transit Company.* (17) June 28.
Proper Location for Trolley Wire on Curves and Corresponding Location of Overhead Frogs.* John H. Barnard. (Paper read before the New York Electric Railway Assoc.) (17) June 28.
Maximum-Traction Trucks *versus* M. C. B. Trucks for City and Suburban Service. H. A. Benedict. (Paper read before the New York Elec. Ry. Assoc.) (17) June 28.
Decision of Board of Arbitration in the Cleveland Case. (17) June 28.
Power Equipment of the Hamburg Rapid Transit System.* (17) July 5.
Train Operation for City Service.* (17) July 5.
Recent Developments in Railway Control.* F. E. Wynne. (Abstract of paper read before the Central Elec. Ry. Convention.) (17) July 5.
Recent Improvements in the Electric Railway System of Providence, R. I.* (17) July 12.
Alameda Avenue Subway in Denver.* (14) July 19.
Repair Shop Practice at Portland, Portland Ry. Light and Power Co.* (17) July 26.
Feeder Tests on the San Diego Electric Railway.* H. Macnutt. (17) July 26.
La Transformation du Réseau Municipal de Tramways à Paris. A. Mariage. (32) Mar.
Der elektrische Ausbau der Stadt-, Ring- und Vorort-Bahnen in Berlin. G. Soberski. (102) Serial beginning Apr. 15.
Elektrischer Lokomotivbetrieb auf Stadtschnellbahnen.* E. C. Zehme. (41) May 29.
Der Spreetunnel der Hoch- und Untergrundbahn in Berlin.* Kemmann. (40) May 31.
Vorschläge zur Verbindung der nördlichen Berliner Vorortbahn mit der Stadtbahn und mit dem Potsdamer Platz. Fr. Schulze. (39) Serial beginning June 20.
Das Selbsttätige Signalsystem auf Schnellbahnen.* O. Wehland. (41) July 17.

Sanitation.

Sewerage and Sewage Disposal at Guildford. C. G. Mason, Assoc. M. Inst. C. E. (Paper read before the Assoc. of Managers of Sewage Disposal Works.) (104) Apr. 25.
Disposal of Paper Mill Wastes.* Edward Hutchins. (Paper read before the Boston Soc. of Civ. Engrs.) (1) May.
Permissible Dilution of Sewage. George W. Fuller, M. Am. Soc. C. E. (41) May.
Sewer Siphons Under New York Subway.* Thad. L. Wilson. (Paper read before the Brooklyn Engrs.' Club.) (60) May.
Cleaning Streets in St. Louis, Mo. (60) May.
House Drainage Regulations on the Continent. Frank R. Durham, Assoc. M. Inst. C. E. (Paper read before the Sanitary Inst.) (104) May 2.
The Main Drainage of Gerrard's Cross.* Arthur Gladwell. (Paper read before the Institution of Mun. and County Engrs.) (104) May 2.
Government Aid in Land Drainage. Arthur E. Morgan. (Abstract of paper read before the National Drainage Congress.) (13) May 8.
Sewage Treatment. R. J. McKenn. (Paper read before the Institution of Mun. Engrs.) (104) Serial beginning May 9.
Improved Air Conditions in a Residence.* Frank Irving Cooper. (Paper read before the Am. Soc. of Heating and Ventilating Engrs.) (101) May 9.
Sewage Treatment at a State Hospital, Tanks and Filters for Treating 575 000 Gallons of Sewage Daily at Norristown.* P. E. Mebus. (14) May 10.
Collection and Disposal of Boston Refuse.* (14) May 10.
Some Structural Features of the Flint, Michigan, Sewerage and Drainage System.* (86) May 14.
Temporary Comfort Stations for Inauguration.* A. R. M'Gonegal. (101) May 16.
Discussion on Principles of Ventilation.* E. Vernon Hill. (101) May 16.

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Sanitation—(Continued).

Details and Heating of Fireproof Factory Building. E. J. Moore. (14) May 17.
Drainage of the Haarlem Lake in Holland.* (14) May 17.
Practical Ventilation. MacD. Dexter. (Paper read before the Southern Gas Assoc.) (24) May 19.
The Government and Public Works of Delhi, India. Tom Salkfield. (Abstract from *Journal*, Sanitary Inst. (13) May 22.
A Test of a Refuse Destructor at Smethwick.* W. Naylor, Assoc. M. Inst. C. E. (104) May 23.
The Design of Siphon and Grit Chambers for the Main Intercepting Sewer, Fitchburg, Mass.* (Abstract from Annual Report, Fitchburg Sewage Disposal Comm.) (86) May 28.
Notes on Sewage Disposal. Geo. W. Swinburne, M. Am. Soc. C. E. (96) May 29.
Studies of Fish Life and Water Pollution. H. W. Clark and George O. Adams. (Abstract of paper read before the International Congress of Applied Chemistry.) (104) May 30.
Plans for the Disposal of New York's Sewage.* (46) May 31.
Recent Progress in the Standardization of Disinfectants. John Morris Weiss. (3) June.
Sewage Purification.* F. H. Tibbetts. (60) June.
The Operation of Sewage Disposal Plant at Columbus, Ohio.* (60) June.
District Steam Heating with High Pressure Steam.* Frederick W. Ballard. (Abstract of paper read before the Ohio Soc. of Mech., Elec. and Steam Engrs.) (64) June 3; (62) May 26.
A Sewer Discharge Diagram.* J. M. M. Greig, A. M. I. C. E. (96) June 5.
Sewage Treatment Works for Fitchburg, Mass.* Frank A. Marston. (13) June 5.
Sewage Disposal by Dilution. Horace S. Griswold. (96) June 5.
Features of Combination Heating in Residence.* (101) June 6.
Miner's Nystagmus. T. Lister Llewellyn. (Paper read before the Mining Exhibition.) (22) June 6.
Opinions Relative to Stream Pollution: Digest of Answers to Series of Questions Prepared by Paul Hansen. (14) June 7.
Sewage Treatment Works at Fitchburg (Imhoff Tanks and Stone Sprinkling Filters).* (14) June 7; (86) June 25.
Plumbing in Hotel Statler, Cleveland.* (101) June 13.
Raising a Sewer While in Service.* (14) June 14.
Sinking a Sewage Pump Well in Silt in El Paso.* (14) June 14.
Lazwell Drainage-Pumping Plant.* (64) June 17.
Hot-Water Heating Extra-Ordinary.* (101) June 20.
Some of the More Recent Municipal Works of Rochdale. S. S. Platt. (Paper read before the Institution of Mun. and County Engrs.) (104) June 20.
Fitchburg Sewage Disposal Plant.* (From Report of the Sewage Disposal Comm.) (96) June 26.
Heating and Plumbing in Country Home.* (101) June 27.
Sewage Pollution Decision in Michigan. (14) June 28.
Aeration as an Aid to Filtration of Sewage. H. W. Clark and George O. Adams. (14) June 28.
Prevention of Disease Versus Cost of Living. Thomas F. Harrington. (Paper read before the Women's Municipal League, Boston.) (19) June 28.
Construction of Tile Pipe Sewers in Chicago.* Herbert Edson Hudson. (60) July.
Mixed Method Garbage and Waste Disposal.* E. B. Stuart. (60) July.
The Covering of Jones' Falls, Baltimore, Md.* (13) July 3.
Studies at the Lawrence Experiment Station upon the Disposal of Sewage Sludge in Deep Tanks. H. W. Clark and G. O. Adams. (13) July 3.
The Treatment of Sewage Discharged into Tidal Waters. H. C. H. Shenton. (Paper read before the Assoc. of Managers of Sewage Disposal Works.) (104) July 4.
The Design and Construction of the Jones' Falls Stream Improvement, Baltimore, Md.* J. J. Frederick. (86) July 9.
Method and Cost of Constructing a 6-Ft. Concrete Storm Water Sewer in Webb City, Mo.* E. W. Robinson. (86) July 9.
Report on Refuse Collection and Disposal in Winnetka and Glencoe, Ill. Samuel A. Greeley. (86) July 9.
Economic Design of Indirect Heating Systems. Frank L. Busey and Willis H. Carrier. (Abstract of paper read before the Am. Soc. of Heating and Ventilating Engrs.) (101) Serial beginning July 11.
Strength of Drain Tile and Sewer Pipe. (14) July 12.
Waste Heat from Gas and Oil Engines for Heating Buildings.* E. F. Tweedy. (Paper read before the National Elec. Light Assoc.) (64) July 15.
The Design of Central Heating Systems. A. G. Christie. (96) Serial beginning July 17.
The London County Council's New Sewage Pumping Station.* (12) July 18.
No Cessation in Construction of the Calumet-Sag Channel. (14) July 19.
Sludge Disposal at Oldham. (14) July 19.
The British Method of Disposing of House Refuse by Crushing and Pulverizing it to a Fertilizing Powder.* James A. Seager. (86) July 23.

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Sanitation—(Continued).

Ventilation System of Hotel McAlpin.* (101) July 25.
High-Pressure Steam Heating *vs.* Hot Water By-Product Plant. Ira N. Evans. (64) July 29.
Notauslass-Kläranlagen.* Hermann Mannes. (7) Jan. 25.
Zur Frage des Fortfalles der Sinkkasten und der Wasserverschlüsse bei den Strasseneinläufen.* Eugen Geiger. (7) Jan. 25.
Einfluss der Heizkörperverkleidungen auf die Wärmabgabe.* C. Reutti. (7) Apr. 19.
Die Bestimmung der Heizkörpergrossen mit Rücksicht auf die Kosten der Projektierung von Heizungsanlagen. C. A. Gullino. (7) Apr. 19.
Luftverbesserung durch Ozonisierung in Badeanstalten. Ludwig Ad. v. Kupffer. (7) Apr. 19.
Untersuchungen über die Wirtschaftlichkeit einer Ferndampfheizungsanlage.* J. Henkelmann. (7) Serial beginning Apr. 26.
Zugweite. O. Krell. (7) May 3.
Pumpwerk Alte Emscher.* Ernst Mautner. (78) Serial beginning May 7.
Noch ein Beitrag zur Frage des Fortfalles der Sinkkästen bei den Strasseneinläufen. F. Moritz. (7) May 10.
Bericht über weitere Betriebserfahrungen mit den Fernwarmwasserheizungs- und Lüftungsanlage im Dresdener Rathause.* Karl Schmidt. (7) May 17.
Die Kläranlage der Stadt Görlitz. Zimmermann. (7) May 17; (39) June 5.
Hygiene der Warmwasser-Versorgungsanlagen. Alex. Marx. (7) Serial beginning May 24.
Ueber die Verwendbarkeit von Torf zum Aufbau von Abwasserreinigungsanlagen.* F. Guth und P. Keim. (7) May 31.
Ein Beitrag zur Lüftungsfrage. M. T. Djuvara. (7) May 31.
Anwendung der für Thermometer gültigen Formeln auf die Abkühlung von Gebäuden.* G. de Grahl. (7) June 7.
Enteignung von Grundstücken anlässlich der Durchführung städtischer Kanalisationsanlagen. Hache. (7) June 7.
Normalbauwerke bei Städte-Kanalisationen.* Paul Schmitt. (7) Serial beginning June 28.
Die Einwirkung des elektrischen Starkstromes auf den menschlichen Körper und erste Hilfe bei elektrischen Unfällen. H. Gerbis. (41) July 3.
Thermische und akustische Isolierungen. Fr. Braikowich. (53) Serial beginning July 4.

Structural.

The Fireproof Building; Its Advantages and Its Weaknesses. H. W. Forster. (58) Oct., 1912.
Paint for Ironwork. G. Basil Barham, A. M. I. E. E. (104) Apr. 25.
The Design and Architectural Treatment of the Shop.* H. V. Lanchester. (29) Apr. 25.
Preventing Settlement Cracks in Stucco Houses.* Ernest McCullough. (67) May.
Water as an Element in Concrete Construction. H. A. Mark. (60) May.
An Electrolytic Theory of the Corrosion of Iron. Bertram Lambert. (Paper read before the Faraday Soc.) (105) May.
The Surface Treatment of Concrete. G. C. Workman. (Paper read before the Concrete Inst.) (104) May 2.
Wood Preservation with Water Gas Tar. Frank C. Mathers and J. N. Moncrieff. (Abstract of paper read before the Indiana Gas Assoc.) (66) May 6.
Repairs to a Reinforced-Concrete Chimney.* C. E. Smith. (13) May 8.
A Method of Proportioning Concrete.* William B. Hunter. (13) May 8.
A Test of Red-Lead Priming Paints.* Cloyd M. Chapman. (13) May 8.
Fire Protection at Lodge & Shipley Plant.* Henry M. Wood. (20) May 8.
Saving a Cathedral with a Diver; How Winchester Was Furnished with a New Foundation.* J. W. Overend. (46) May 10.
Grinding Wheel Sparks, How They Indicate the Character of Steel.* R. G. Williams. (From *Grits and Grinds.*) (19) May 10.
Stopping Planes in Reinforced Concrete. Edward J. Stead. (96) May 15.
The Practical Strength of Structures.* (11) May 16.
Elastic Hysteresis.* Earl B. Smith. (14) May 17.
Poured Concrete Buildings, D., L. & W. R. R.* (18) May 17.
High Eight-Acre Exposition Building with a Timber Frame.* H. D. Dewell. (14) May 17.
The Protection of Concrete Structures from Alkali and Other Destructive Agents. W. D. Rohan. (86) May 21.
Physical Tests of Oil-Mixed Portland Cement Concrete.* Logan Waller Page. (104) May 23.
The Stability of Brick Chimneys.* Harold Cane. (Abstract of paper read before the Concrete Inst.) (104) May 23; (22) May 16.
Riveting Pressures. (14) May 24.
Erecting a Steel Smokestack on a High Roof. (14) May 24.

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Structural—(Continued).

Baltimore & Ohio Timber-Treating Plant, Newly Completed Layout at Green Spring, W. Va.* F. J. Angier. (14) May 24.
Underpinning a Nine-Story Column; 200-Ton Load Suspended from Needle Girders While Pipes Were Driven and Concreted Under Them.* Walter J. Willis. (14) May 24.
Shoring a Theater Wall with Cantilever Needlebeams. (14) May 24.
The Resistance of Steel-Framed Sheds to Wind Forces.* Albert S. Spencer. (12) Serial beginning May 30.
Steel Gantry for Building the New Government Stationery Office.* (12) May 30.
Eight-Story Concrete Building Without Interior Columns.* H. D. Loring. (14) May 31.
Bending Strength of Yellow-Pine Timber, Safe Loads for Beams and Girders of Standard Dimensions.* J. J. Morgan. (14) May 31.
Rapid Execution of Heavy Foundation Work. (14) May 31.
Historic Failures of Engineering Structures. Horace R. Thayer. (58) June.
Cities Unburnable.* F. W. Fitzpatrick. (10) June.
Why the Giant Skyscrapers Are Safe.* J. F. Springer. (10) June.
Constancy of Volume Accelerated Tests in Portland Cement. Max Gary. (Paper read before the Inter. Assoc. for Testing Materials.) (67) June.
Preserving Fence Posts from Decay. (96) June 5.
The Microscope in the Iron and Steel Industry. Albert Sauveur. (Abstract of a paper read before the Am. Iron and Steel Inst.) (20) June 5.
A Modern Timber Drying Plant.* (12) June 6.
Long Beach Auditorium Disaster.* (14) June 7.
Bending Moments in Continuous Reinforced-Concrete Beams. Sanford E. Thompson. (14) June 7.
A New Four-Lift Spiral-Guided Holder for Oldham.* (66) Serial beginning June 3.
The Flat Slab System in Floor Construction.* W. G. Ure. (96) Serial beginning June 12.
Some Notes on the Proposed L. C. C. Regulations for Reinforced Concrete.* Percy J. Waldram. (11) Serial beginning June 13.
Copper in Steel, Its Influence on Corrosion. D. M. Buck. (Paper read before the Am. Chemical Soc.) (47) June 13.
Underpinning on Inclined Strata. (14) June 14.
Housing Problems and Restrictions in Large Cities. (14) June 14.
What Brick Houses Cost.* (76) June 15.
Blended or Sand Cements; Results of the Study and Experience of the U. S. Reclamation Service. Rapier R. Coghlan. (13) June 19.
The Distribution of Stress in a Cement Briquette.* E. G. Coker. (Paper read before the Inter. Assoc. for Testing Materials.) (19) June 21.
Action of Alkali and Sea Water on Cements. (14) June 21.
The Corrosion of Cast Iron Reviewed. Richard H. Gaines. (24) June 23; (20) June 5.
Allowable Heights and Areas for Factory Buildings. (86) June 25.
Eliminating Columns in a Store Front.* (14) June 28.
The Deflection Method of Calculating the Strength of Columns and Stanchions.* A. J. Murray. (95) Serial beginning July.
Gasholders: Their Construction and Use.* Ernst Körting. (Paper read before the German Gas Assoc.) (66) July 1.
Some Tests of Flat Plates of Glass.* Edward Godfrey. (86) July 2.
Advantages of the Quantity System for Estimating Bidding Prices for Building Construction.* (86) July 2.
Cost of Constructing a Camp to Accommodate Forty Laborers.* Clark A. Bryan. (86) July 2.
Municipal Building Laws in the United States. R. Fleming. (13) July 3.
Building a Reduction Plant. Herbert Lang. (103) July 5.
A Study of Available Data on the Autoclave Test. (14) July 5.
Method of Checking Economical Height of Office Buildings. (14) July 5.
Design of the Woolworth Building.* S. F. Holtzman, M. Am. Soc. C. E. (14) July 5.
Waterproofing Cement Concrete and Cement Renderings.* J. H. Kerner-Greenwood. (Paper read before the Incorporated Soc. of Clerks of Works of Great Britain.) (104) July 11.
The Effect of Various Substances on the Rate of Corrosion of Iron by Sulphuric Acid. O. P. Walts. (Paper read before the Am. Electrochemical Soc.) (73) July 11.
The Development and Status of the Wood Preserving Industry.* E. A. Sterling. (Paper read before the Inter. Congress of Applied Chemistry.) (19) July 12.
Comparison of Column Formula.* E. L. Lasier. (14) July 12.
Construction of a Reinforced Concrete Factory in Cambridge, Mass.* (86) July 16.
The Service Equipment of the Samaritan Hospital, Troy, N. Y.* C. F. Herington. (13) July 17.
A Workman's Cottage for 150 Pounds.* Frank H. Heaven. (104) July 18.
Load-Extension Diagrams.* W. E. Dalby. (Paper read before the Royal Soc.) (11) July 18.

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Structural—(Continued).

The World's Highest Office Building.* Charles E. Knox. (27) July 19.
Determination of Moments in Continuous Beams.* W. A. Slater. (14) July 19.
Reinforced Concrete Details of a Large Paint Shop.* (14) July 19.
Handling Cement in Bulk.* J. H. Libberton. (14) July 21.
Results of Field Tests of Concrete Disintegration by Immersion in Sea Water.* P. H. Bates, A. J. Phillips and Rudolph J. Wig. (From *Technologic Paper No. 12*, U. S. Bureau of Standards.) (86) July 23; (13) July 10.
The Construction and Use of Empiric Formulas.* Cyrus T. Brady, Jr. (13) July 24.
Design of Standard Reinforced-Concrete Retaining Walls.* H. M. Gibb. (13) July 24.
Powerful Influence of Basic Pigments in Protecting Metals from Corrosion.* Henry A. Gardner. (14) July 26.
Note sur le Calcul des Poutres en Beton Armé.* Tessier. (43) Mar.
Note Complementaire sur le Calcul des Hourdis en Béton Armé.* J. Résal. (43) Mar.
Action des Acides, des Huiles et des Corps Gras sur le Béton. (84) Apr.
Applications Pratiques des Instructions Ministerielles du 20 Octobre, 1906 relatives au Calcul des Pièces Fléchies en Beton Armé.* N. de Tedesco. (33) Apr. 26.
Rectification des Matières Premières Chimiquement Incomplètes. (84) May.
Le Nouvel Abattoir d'Angers (Marne-et-Loire.)* Jules Blitz. (35) Serial beginning May.
Sur l'Activité Relative des Grains de Cement selon leur Degré de Finesse. (84) June.
Divergences entre la Structure et la Composition de Certain Aciers.* Brès. (93) July.
Graphische Tafeln für Eisenbetonträger.* W. Vieser. (81) Pt. 3.
Die Berechnung der Rahmenträger mit besonder Rücksicht auf die Anwendung. Fr. Engesser. (49) Serial beginning Pt. 1.
Das Neue Rathaus der Stadt Hannover.* Rowald. (81) Pt. 4; (40) June 21.
Versuche mit Eisenbeton-Säulen.* M. Rudeloff. (51) Serial beginning Sup. No. 10.
Entwurfskizzen für den Neubau eines Königlichen Opernhauses in Berlin.* Hermann Dernburg. (40) Jan. 29.
Zur Kenntnis des "Weissen Stern-Zementes" der Portland-Zementfabrik "Stern" in Finkenwalde bei Stettin. M. v. Glasenapp. (52) Mar. 15.
Rechnerische Auflösung von Fünfgliedrigen Elastizitätsgleichungen.* A. Ostenfeld. (69) Apr.
Die Kassettenplatten als Dacheindeckung, Fachwerkfüllung und Fusswegbelag.* Franz Czech. (69) Apr.
Eine Graphische Bestimmung der Maximalmomentenflächen bei Trägern mit Beweglicher Last.* R. Schumacher. (69) Apr.
Festigkeit von Ziegelmauerwerk und ihre Abhängigkeit von der Art des Mörtels.* O. Wawrziniok. (80) Apr. 22.
Einrichtungen Englischer und Amerikanischer Materialprüfungsanstalten.* Viktor Luftschitz. (53) Seral beginning Apr. 25.
Dacheindeckungen mit Gebrannten Ziegeln.* (80) Apr. 29.
Feuerschutz.* Bösenberg. (69) May.
Versuche an Schmiedeeisernen Blechträgern.* K. A. Müllenhoff. (69) May.
Das Neue Stadthaus in Bremen.* Gabriel von Seidl. (51) Serial beginning May 3.
Stampfasphaltarbeiten im Eigenbetrieb unter Benutzung einer festehenden Gemauerten Darre.* Brech. (39) May 5.
Ueber den Einfluss des Zements auf die Druckfestigkeit im Kalkmörtel.* Brabandt. (40) May 7.
Ueber Schalldurchlässigkeit von Baumaterialien und Ausgeführten Wänden. Rudolf Ottenstein. (7) May 10.
Die Neuen Staatlichen Bauten in Bad Kissingen.* Max Littmann. (51) Serial beginning May 14.
Der Beigungsfeste Rahmen mit Flächenlagerung.* Max Ritter. (107) May 17.
Amerikanische Getreidetrockner.* J. F. Hoffmann. (48) May 24.
Das Neue Kaiser-Friedrich-Bad in Wiesbaden.* (40) Serial beginning May 24.
Ueber Fundamentplatten für Einzellasten unter Besonderer Berücksichtigung der Kreisplatte.* Lewe. (78) May 26.
Die Erweiterungsbauten in Eisenbeton der Deutsch-Amerikanischen Lederwerke Becker and Co., Offenbach-Bürgel A. M.* Jean Wörrlein. (78) Serial beginning May 26.
Unfallverhütungsvorschriften für Eisenbetonbau. B. Löser. (78) May 26.
Die Teilung Trapezförmiger Flächen in *n* Inhaltsgleiche Streifen.* Henkel. (78) May 26.
Bruchversuche mit Hetzerbindern.* Ch. Chopard. (107) May 31.
Die Verwertung der Hochofenschlacken zu Bauzwecken.* E. Elwitz. (48) May 31.

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Das Verhältnis Zwischen Temperatur und Stabspannung bei Zugversuchen. S. J. Druschinin. (69) June.
Beitrag zur Berechnung von Steifrahmen.* A. Haupt. (69) June.
Das Deutsche Opernhaus zu Charlottenburg.* Heinrich Seeling. (51) Serial beginning June 4.
Gebaudeblitzschutz. S. Ruppel. (41) June 5.
Abgeänderter Entwurf zum Ausbau des Freiburger Domes.* Albert Hofmann. (51) June 7.
Preisbewertung von Portlandzement.* Spindel. (80) June 7.
Doppelt Armierte Eisenbeton-Querschnitte.* Otto Leuprecht. (107) June 7.
Beton und Eisenbeton in Danemark.* (80) June 10.
Verfahren Einer Raschen und Genauen Massenberechnung von Säulenfundamenten. G. Sickinger. (78) June 12.
Eisenbetonbauten für Zellulosefabrikation.* J. Rieser. (107) June 14.
Ueber Erschütterungen.* R. Berger. (7) June 14.
Das Deutsche Stadion im Grunewald bei Berlin.* (40) June 14.
Das Deutsche Stadion Ganz aus Beton und Eisenbeton Erbaut.* (80) June 14.
Eiskelleranlagen in Eisenbeton.* Hans Schafer. (78) July 1.
Reiner Oder "Verfälschter" Portlandzement? Ernst Schick. (78) July 1.
Thermische und Akustische Isolierungen. Fr. Braikowich. (53) Serial beginning July 4.

Topographical.

Stereo Photo Surveying.* Henry Hess. (58) May.
Surveying by Photography. Benj. Smith Lyman. (58) May.
Etude sur le Tracé des Courbes par Rayonnement.* James Boudet. (35) Serial beginning July.
Zweckverband und Vermessungswesen. Abendroth. (39) May 20.

Water Supply.

Notes on the Laramie Tunnel.* David W. Brunton. (56) Vol. 43.
The Lowell Water Works and Some Recent Improvements.* Robert J. Thomas. (28) Mar.
Report of Committee on Water Consumption Statistics and Records. (New England Water Works Assoc.) (28) Mar.
Hydroelectric Developments at Niagara Falls.* Albert F. Ganz. (8) Apr.
The Importance of Meteorological Data in Engineering. George S. Bliss. (2) Apr.
Water Conservation in Europe.* Kenneth C. Grant. (98) Apr.
Two-Stage Centrifugal Pump.* (12) Apr. 25.
Porto Rico Irrigation Service.* W. L. Squire and F. H. Knapp. (36) May.
Waterproofing Huntington Water Tower.* F. William Stocker. (60) May.
The Cause and Detection of Water Waste. (96) May 1.
The Distributing System of New York's Water Supply. (96) May 1.
Note on James Thomson's V-Notches. H. S. Rowell. (11) May 2.
Leaks in the Assouan Dam.* (12) May 2.
Method of Constructing a Hydroelectric Power House and Dam on Sand Foundations.* (86) May 7.
The Elimination of Taste in Water Treated with Calcium Hypochlorite.* Arthur Lederer and Frank Bachmann. (Abstract of paper read before the Ill. Water Supply Assoc.) (13) May 8; (96) July 3.
An Interesting Hydraulic Investigation.* (Report of the Ontario Hydro-Electric Power Comm.) (96) May 8.
The Efficiency of Coagulating Basins. W. F. Monfort. (Paper read before the Illinois Water Supply Assoc.) (96) May 8.
Hydro-Electric Possibilities of the Maitland River, Ontario. H. G. Acres. (Report to the Ontario Hydro-Electric Power Comm.) (96) May 8.
Unestimated Cost in the Development of Irrigation Projects. (14) May 10.
Traveling Crane for Casting Concrete Blocks for Kensico Dam.* (14) May 10.
Appraisal of Waterworks Properties. Douglas A. Graham. (Abstract of paper read before the Illinois Water Supply Assoc.) (14) May 10.
The Rainfall and Flood Conditions in Ohio, Mar. 23 to 28, 1913.* J. Warren Smith. (19) May 10.
Mockfjärd Hydroelectric Development, 20 000-Horsepower Plant in Sweden.* (14) May 10.
Fire Streams from Small Hose and Nozzles.* Virgil R. Fleming. (Abstract of paper read before the Illinois Water Supply Assoc.) (14) May 10.
Emergency Installation of a Sterilization Plant in England. Alec. C. Jarvis. (Abstract of paper read before the Ill. Water Supply Assoc.) (14) May 10.
McCalls Ferry Hydro-Electric Plant.* Charles H. Bromley. (64) May 13.
Cost of Constructing by Contract Water Pipe Extensions Aggregating 17.7 Miles in Chicago in 1912. (86) May 14.
Construction of the Kachess Dam, Washington.* (13) May 15.
The Cost of Irrigation Works per Acre Supplied with Water. (13) May 15; (86) June 4.
Baths for Miners.* (Regulations Under Coal Mines Act by Home Secy.) (57) May 16; (22) May 16.

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Water Supply—(Continued).

Management of the Danville, Ill., Waterworks.* (14) May 17.
Municipal Power Plant of Eugene, Ore.* (27) May 17.
The Design and Construction of a 2 000 000 Gal. Circular, Covered, Reinforced Concrete Reservoir at Fort Dodge, Iowa.* C. T. Harding. (86) May 21.
Diagrams of Discharge Over Sharp Crested Rectangular Weirs, Without End Contractions, for Heads on Crest from 0.20 Ft. to 10 Ft.* R. R. Lyman. (From *Bulletin No. 5*, Utah Eng. Exper. Station.) (86) May 21.
Construction Features of Bear Creek Hydraulic-Fill Dam, Jordan River Development, Vancouver Island and British Columbia.* C. E. Blee (86) May 21.
Methods and Devices for Measuring Water for Irrigation. Albert Eugene Wright. (86) May 21.
Reports on Filtering the Croton Water Supply. (13) May 22.
Water Waste Investigation. W. D. Gerber. (Paper read before the Illinois Water Supply Assoc.) (96) May 22.
Some Water Supply Problems of the West. R. O. Wynne-Roberts, M. Inst. C. E. (Paper read before the Regina Eng. Soc.) (96) May 22.
The Government and Public Works of Delhi, India. Tom Salkfield. (Abstract from *Journal*, Sanitary Inst.) (13) May 22.
The Hydro-Electric Development of the Braden Copper Co.* C. G. Newton. (13) May 22.
The Humphrey Internal-Combustion Pump and Some Proposed Developments.* (11) May 23.
Twin Falls Hydroelectric Development.* George C. Newton. (14) Serial beginning May 24.
Repairs to Breaks in St. Louis Reservoir Walls.* Edward E. Wall. (14) May 24.
Eight-Mile Concrete Conduit at Baker, Oregon. (14) May 24.
Agriculture, Electricity and Irrigation.* Putnam A. Bates. (46) May 24.
Method of Moving a 100 000 Gallon Elevated Water Tank.* (86) May 28; (14) May 31.
A Study Made to Determine Equitable Water Rates for the City of St. Louis, Mo. Edward E. Wall. (Abstract of Report to the Board of Public Improvements.) (86) May 28.
The Effect of Artesian Water Upon Galvanized Steel Pipe at Moline, Ill. (86) May 28.
An Interesting Filter Installation.* (96) May 29.
Snow Surveys for Predicting Stream Flows.* J. Cecil Alter. (13) May 29.
The World's Largest Water Power Plant at Keokuk.* (27) May 31; (10) July.
Construction Work on the Prairie du Sac Power Plant.* (14) May 31.
Failure of the Reservoir at Johnson City, Tennessee.* A. H. Purdue. (14) May 31.
Efficient Handling of Lime and Chemicals at the Columbus, O., Water Softening and Purification Works. Charles B. Hoover. (60) June.
A Model Water Supply for Manufacturing Purposes (Tennessee Coal, Iron and Railroad Co.).* (60) June.
Water Works of Daytona, Fla.* Geo. A. Main. (60) June.
Hydraulic Power Developments in the South.* (10) June.
Construction of the Grand Rapids Filtration Plant.* L. D. Cutcheon. (60) June.
The Design of the Water Filtration Plant at Mt. Vernon, Ill. S. B. Severson. (Paper read before the Illinois Water Supply Assoc.) (86) June 4.
Method and Cost of Making an 18-In. Tap on a 24-In. Water Main Without Interrupting Service at Columbia, South Carolina. F. C. Wyse. (86) June 4.
Method of Concreting in Freezing Weather at the Timiskaming Dam, Ottawa River Storage, Ontario. Emile Low. (86) June 4.
The Failure of the Sand Canyon Pressure-Tunnel Siphon of the Los Angeles Aqueduct.* Burt A. Heinly. (13) June 5; (14) June 7.
Origin and Theory of the Pitot Tube.* A. E. Guy. (13) June 5.
Address on Water Purification. Charles Clemesha Smith. (Paper read before the Institution of Water Engrs.) (104) June 6.
Boston's New High Pressure Fire Hydrant.* (14) June 7.
Klamath River Hydro-Electric Development.* J. C. Boyle. (14) June 7.
The Morena Rock-Fill Dam, California.* (13) June 12.
The Valuation of Waterworks Undertakings on Transfer to Municipal Authorities. E. J. Silcock, M. Inst. C. E. (Paper read before the Institution of Water Engrs.) (104) June 13; (66) June 10.
Water Supply of Jersey.* Alfred J. Jenkins, Assoc. M. Inst. C. E. (Paper read before the Institution of Water Engrs.) (104) June 13.
Irrigation Works in India.* John Benton. (29) June 13.
Concrete Pipe and Overflow Basins for Distributing Irrigation Water.* Eugene C. Mills. (14) June 14.
Design and Operating Features of Motor-Driven Pumps.* Charles A. Carpenter. (27) June 14.
Cost of Hauling Construction Materials for the Hemlock Reservoir Dam and Pipe Line, Bridgeport, Connecticut, Waterworks.* (86) June 18.
The Disinfection of Lake Michigan Water with Calcium Hypochlorite at Waukegan. Lake Forest and Winnetka, Ill. W. J. Allen. (Paper read before the Illinois Water Supply Assoc.) (86) June 18.

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Water Supply—(Continued).

Construction Methods Employed on the Shafts and Tunnel of the Under-City Section of the Catskill Aqueduct.* (From Reports of the Board of Water Supply of the City of New York.) (86) June 18.
A Concrete Lining with a Felt Waterproofing; Eden Park Reservoir, Cincinnati, O., Water Works.* (86) June 18.
Methods of Rapid Sand Filtration. George A. Johnson. (Abstract from U. S. Geol. Survey Report.) (96) June 19.
Sanitary Precautions to Protect the Watershed of a City Water Supply During the Construction of an Electric Railway. (From Report of Water Commrs. of Springfield, Mass.) (13) June 19.
The Completion of the Los Angeles Aqueduct.* Burt A. Heinly. (13) June 19.
Filling a Tunnel Cave-in by the Hydraulic Method.* Donald F. McLeod. (13) June 19.
Cutting a 20-In. Water-Main Connection into a 20-In. Tee.* (13) June 19.
A New Design for Waterworks Intake Cribs.* W. D. Barber. (13) June 19.
Animal Growths in Water Pipes. Samuel C. Chapman, M. Inst. C. E. (Paper read before the Institution of Water Engrs.) (12) June 20; (104) July 4.
Wakefield Corporation Waterworks.* Charles Clemesha Smith, M. Inst. C. E. (Paper read before the Institution of Water Engrs.) (104) June 20.
Water Purification.* (47) June 20.
Reasons for Reporting Water Analysis in Ionic Form in Parts Per Million. R. B. Dole. (14) June 21.
Laying Submerged Water Main at Milwaukee.* (14) June 21.
Supreme Court Decision on Water Power in St. Mary's River. (14) June 21.
Pressure Regulation for Hydro-Electric Plants.* C. A. Tupper. (82) June 21.
Efficiency of Coagulating Basins: Observations on the Operation of the Water-Clarifying Plant at St. Louis. (14) June 21.
Report on Allentown Water Supply. (14) June 21.
"Tuning Up" the Minneapolis Filter Plant.* (14) June 21.
Moose Jaw Water-Supply System.* (14) June 21.
Repairing a Break in a 42-Inch Force Main at Duluth. E. W. Kelly. (14) June 21.
Corrosion of Lead. Richard H. Gaines. (14) June 21.
Cleaning a Large Settling Reservoir.* Joseph W. Ellms. (14) June 21.
Reservoir Storage in Relation to Stream Flow.* William J. E. Binnie and Herbert Lapworth. (Paper read before the Institution of Water Engrs.) (66) June 24; (104) June 27.
Methods and Labor Cost of Constructing the 39 000 000-Gal. Mechanical Water Filtration Plant at Minneapolis, Minn.* W. N. Jones, Assoc. M. Am. Soc. C. E. (86) Serial beginning June 25.
The Application of Ozone to Water Purification, with Special Reference to European Practice. Russell Spaulding. (86) June 25; (96) July 10.
Toronto Waterworks Extensions. (96) June 26.
Classification of Water Consumption in Milwaukee, Wis. (13) June 26.
Raystown Hydro-Electric Plant: A Concrete Dam with Stepped Spillway.* (14) June 28.
Raising the Assuan Dam.* (14) June 28.
Providing for Ten Million, New York's Big Drinking Cup Will Eventually Supply Five Hundred Million Gallons per Day. J. F. Springer. (10) July.
An Overestimated Value, Popular Misunderstanding as to the Actual Capacity, Adaptation and Worth of Water Power as Compared with Steam Power.* Reginald Pelham Bolton. (10) July.
Elephant Butte Dam.* (67) July; (14) May 17.
The Action of Alkali on Cement Pipes. Will L. Brown. (67) July.
Test of Anchor Bolts at Keokuk, Iowa. Charles Keller, M. Am. Soc. C. E. (100) July.
Forests and Their Effect on Climate, Water Supply and Soil.* J. C. Stevens. (Paper read before the Oregon Soc. of Engrs.) (1) July.
Water Power Decision of the U. S. Supreme Court. (105) July.
Filtration Plant at McKeesport, Pa.* E. C. Trax. (60) July.
The Design and Construction of Works for Utilizing the Flow of a Spring for Pumping and Water Supply of Ada, Oklahoma.* E. E. Harper. (86) July 2.
Cost of Constructing Extensions to the Water System of Ridgely, Md.* Clark A. Bryan. (86) July 2.
Pressure Filtration Plant at Harleybury, Ontario.* (96) July 3.
A Method of Removing Suspended Colloidal Clay from Drinking Water. M. C. Doynel. (From *La Technique Sanitaire e Municipale*.) (13) July 3.
The Use of Hydraulic Lime for a Masonry Dam. Guy S. Newkirk. (From *Journal of Engineering*, Univ. of Colorado.) (13) July 3; (14) June 14.
Mechanical Filtration Plant at Clarksburg.* H. W. Streeter. (14) July 5.
Storing Lime for Water Softening (Columbus, O.).* Charles P. Hoover and C. J. Clarke. (14) July 5.
Practical Notes on the Location and Setting of Water Meters. H. M. Lofton. (Paper read before the Southwestern Water Works Assoc.) (86) July 9.
Irrigation Pumping Plants. (14) July 12.

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Water-Supply System in the Fifty-Five-Story Woolworth Building, New York.* (14) July 12.
Test of a Two-Stage Turbine Pump. A. A. Potter and W. W. Carlson. (64) July 15.
A Study in Economic Reservoir Design with Special Reference to the New 6 000 000 Gallon Reinforced Concrete Reservoir at Muskogee, Okla.* (86) July 16.
The Typhoid Epidemic at Albany, N. Y., Due to the Flooding of the Water Filters.* (86) July 16.
A 19 000 Horsepower Vertical-Shaft Pelton-Type Waterwheel Under 1 015 ft. Head.* (13) July 17.
Excavation for the Arrowrock Dam, Idaho.* Charles H. Paul. (13) July 17.
The Paterson System of Rapid Filtration.* (11) July 18.
New Reservoirs in Italy and Sardinia.* (12) July 18.
Antelope Valley Siphon, Los Angeles Aqueduct.* Wm. W. Hurlbut. (14) July 19.
Dry Feed for Chemicals Used in Water Purification.* Allen Hazen. (14) July 19.
An Example of the Purchase Under Specifications of Chemicals for Use in Water Purification. (86) July 23.
Water Waste Prevention in New York City. I. M. de Varona. (96) July 24.
A Reinforced-Concrete Double-Deck Water Tank. (13) July 24.
Auxiliary Water Supply for the Fire Protection of San Francisco.* A. J. Cleary. (14) July 26.
Water Sterilization by Ultra-Violet Rays.* Max von Recklinghausen. (27) July 26; (19) June 7.
Waterworks Extensions at Para.* (14) July 26.
Stabilité des Conduites d'Eau de Grand Diamètre; Note Complementaire. Goupil. (43) Mar.
La Distribution d'Eau d'Ougrée.* Jos. Dumont. (30) Apr.
Les Nouveaux Aperçus de M. Allievi sur la Théorie du Coup de Bélier. Goupil. (43) May.
Barrages des Lacs Artificiels. Luigi Luiggi. (84) May.
Le Réservoir de Chingford, près de Londres, et les Pompes Hydrauliques à Gaz, Système Humphrey.* Ch. Dantin. (33) May 3.
Eisenbeton-Wasserturm der Stadt Wohlau i. Schles.* Karl Schaaf. (51) Sup. No. 11.
Versuche an Becherturbinen.* Ernst Reichel und W. Wagenbach. (48) Serial beginning Mar. 22.
Untersuchung einer Hochdruckkreiselpumpe im Hydromechanischen Versuchslaboratorium der k. k. Technischen Hochschule zu Wien.* Richard Katzmayr. (53) Serial beginning Apr. 4.
Zur Ermittlung der Schwingungen im Wasserschloss. Ph. Forchheimer. (48) Apr. 5.
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*Illustrated.

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AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

This Society is not responsible for any statement made or opinion expressed in its publications.

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AMERICAN SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

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CONCRETE BRIDGES: SOME IMPORTANT FEATURES IN THEIR DESIGN.

By Walter M. Smith, Sr., M. Am. Soc. C. E., and
Walter M. Smith, Jr., Jun. Am. Soc. C. E.

To be Presented November 5th, 1913.

It is the object of this paper to bring out several important features in some concrete bridges recently designed by the writers.

Reinforced concrete is now being used in the construction of bridges of all three types: arch, girder, and truss; in fact, there is a bridge across the Seine at Avranches, France, which combines all three types: an arch span of 220 ft., two girder spans of 34 ft. each, and a truss span of 100 ft. There are two girder bridges near Pittsburgh, Pa., one of 75, and the other of 67 ft. span. In Nashville, Tenn., there is a railroad bridge which has two 95-ft. spans, consisting of reinforced concrete bowstring trusses.

The great advantage of concrete over stone for bridges is, of course, in its economy. The concrete bridge has an additional advantage in being stronger and much more reliable, due to the absence of joints.

The mortar in the joints of a stone arch is only from one-fifth to one-tenth as strong as the stone, and all the joints are never completely

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

filled with mortar. In arch work it is very difficult to fill completely with mortar an accurately cut joint of considerable area and small thickness. The writers are very strongly of the opinion that there has never been constructed a large stone arch in which every joint was completely filled with mortar. They have seen first-class stone and brick masonry torn down, in which not more than 75% of the space in the joints was filled with mortar. On the other hand, they have often had to excavate concrete (which had not been built with special care, but with a very cheap class of labor) in which there were no voids whatever.

The following is an example of the difference in cost of construction of concrete and stone arches. In the Manhattan anchorage of the Manhattan Bridge in New York City, the cost of the labor alone in setting the stone in arch work was $5 per cu. yd. The stone itself cost about $25 per cu. yd., delivered at the site, therefore the cost of the finished masonry, including cement, was more than $30 per cu. yd. The cost of this arch stone would have been much greater had it not been for the fact that it was included in a contract for a very large quantity of coursed dimension stone masonry, so that the cost of the latter governed the price of the arch work.

In the Rye Outlet Bridge, a reinforced concrete arch bridge of five spans of about 127 ft. each, designed by the writers, and built by the New York Board of Water Supply, near Valhalla, N. Y., each arch span, containing about 400 cu. yd., was built in an average of 10 hours. There were about 40 men working 10 hours on each span, therefore there were 400 man-hours on each span, or an average of 1 cu. yd. per man per hour. These men were paid from $1.50 to $1.75 per day of 8 hours. The cost of the labor, therefore, was about $0.22 per cu. yd. The net cost of the materials was about $4.25 for concrete, and $5 for steel, forms, etc., giving a total net cost of about $10 per cu. yd., as compared with a little more than $30 for stone masonry. The actual price of this concrete, including the contractor's profit, was $12.50, and of the stone about $34.00.

There is one case in which the stone bridge is preferable to the concrete. If esthetic features are paramount, and economy is not to be considered, then the stone bridge, on account of its adaptability to architectural ornamentation may be more desirable; yet, even in this

Fig. 1.—Connecticut Avenue Concrete Arch Bridge, Washington, D. C.

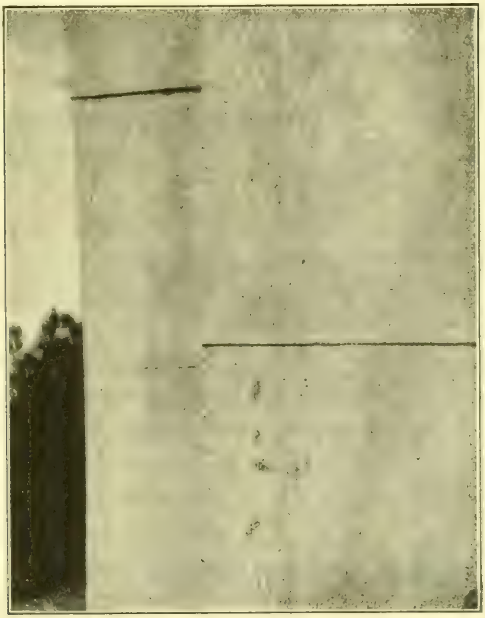


Fig. 2.—Tool-Dressed Faces of Blocks, Connecticut Avenue Bridge.

case, with modern improvements in methods of casting the concrete faces and afterward dressing them with pneumatic tools of various kinds, the concrete bridge can be made almost as handsome as the stone bridge at much less than half the cost.

The writers have heard doubts expressed by engineers as to the weathering qualities of tool-dressed concrete faces. There is ample proof that concrete surfaces, if properly proportioned and cast, may be dressed with any kind of tool, and will weather much better than sandstone, and almost as well as granite.

Fig. 1 is a view of the Connecticut Avenue concrete arch bridge, in Washington, D. C., in which the voussoirs of the arches and quoin blocks of the piers are of concrete with a mortar face about 1 in. thick, composed of granite dust and cement, the exposed faces being patent-hammered with a pneumatic tool after thorough setting. In dressing these blocks it was found that considerable time had to be allowed after they were made before they could be cut, as otherwise the dust would stick to the blades of the hammer and be driven up between them, breaking the tool.

In the winter of 1905, when this bridge was being built, the writers were residing in Washington, and paid particular attention to its construction. In the summer of 1910, in passing through the city, the photograph, Fig. 2, was taken, showing the faces of some of the voussoirs and quoins. The tool-dressed faces on these blocks were in perfect condition, and appeared as though they had been dressed only a short time.

This paper is largely a plea for an arch consisting of two ribs, rather than one with a solid soffit; with narrow rather than wide ribs, and with deep ribs of I-section rather than of rectangular section. It is also especially a plea for the three-hinged as compared with the fixed and two-hinged arches.

There are three very important advantages that the three-hinged arch has over the other types. First, in the simplicity and quickness of its analysis; second, in its adaptability to sites where rock foundation is at too great a depth to be reached; and third, the temperature stresses are entirely eliminated.

The abutments or piers of a three-hinged arch may be founded on slightly compressible material without doing any harm whatever,

whereas the slightest yielding in the abutment or pier of a fixed or two-hinged arch is sure to develop cracks in the arches.

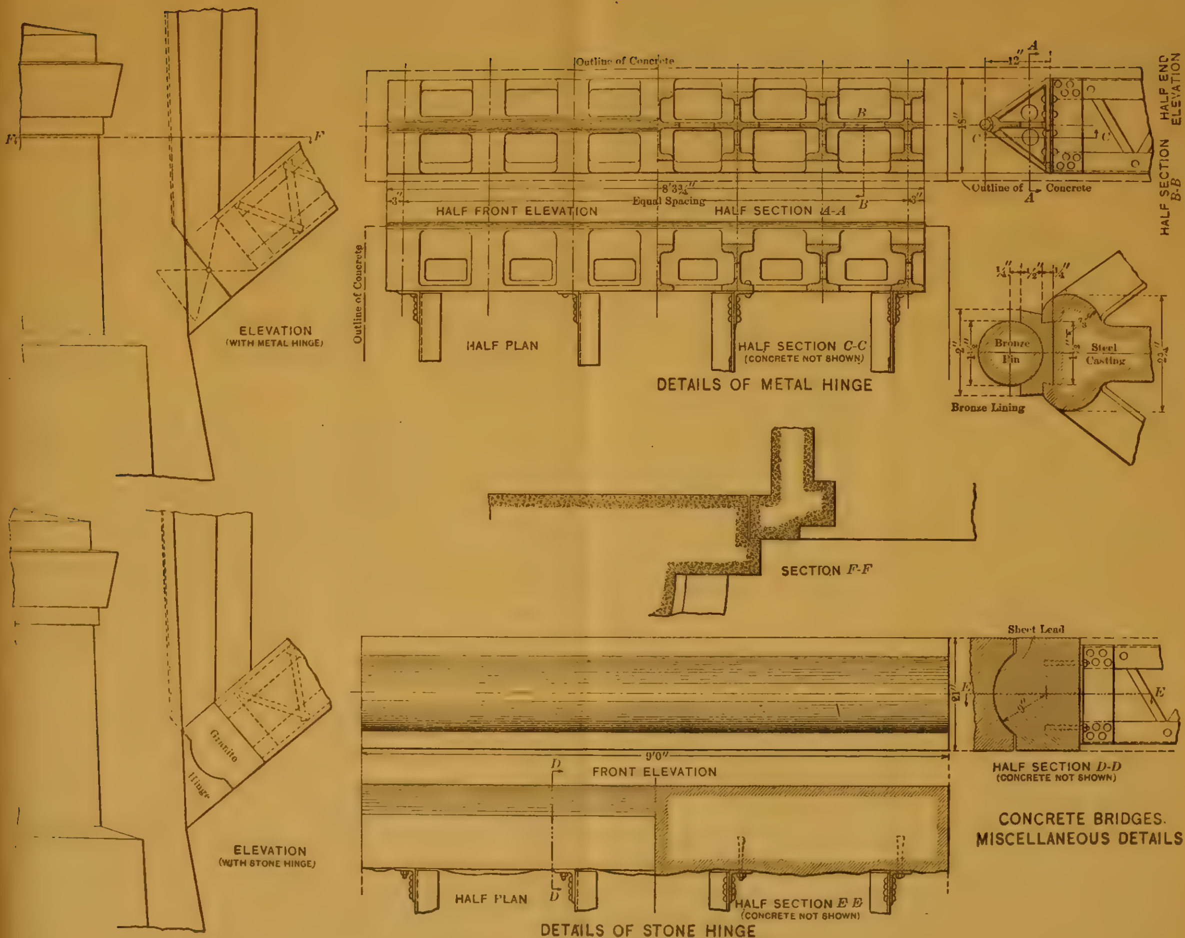
As the three-hinged arch is merely two struts pivoted at the springing line and at the crown, and curved to follow the line of the equilibrium polygon, they will rise or fall at the crown to accommodate changes in the length of the struts due to changes of temperature.

If the bridge above the arch has been designed so that the amounts and positions of the loads on the arch ribs are known, a depth of arch rib may be assumed, its weight computed, and a force polygon and pressure line—or equilibrium polygon—drawn for the arch; the arch may then be drawn, and the stresses computed at the various joints. This entire process can be done with a slide-rule in a single day by a competent man. It very seldom takes more than three trials to fix all the dimensions of a three-hinged arch, whereas it will take several days for each analysis of the fixed arch.

The correct center line for the three-hinged arch should be drawn as follows: Assume the arch to have one-half the span fully loaded and no live load on the other half. Draw the equilibrium polygon for both the loaded and unloaded sides, then draw a line for the center line of the arch midway between the two polygons, as nearly as may be, by taking not more than three centers. It is known that the equilibrium polygons for the arch fully loaded and with no load will lie between the polygons for the half loaded and half unloaded sides; therefore, it is known that the center line drawn is for the most extreme positions of the equilibrium polygon. This may be called drawing a pressure line, and building an arch around it, and is the economical way to design an arch, as the writers can testify from experience.

The three-hinged arch has two slight disadvantages as compared with the fixed arch. First, the cost of the hinges; and second, its somewhat awkward appearance on account of the necessarily increased thickness at the haunches. The second of these cannot be avoided, but the saving in concrete in an arch of large span much more than pays for the hinges.

Fig. 3 shows two bridges which are identical in design above the arch ribs: one consists of two fixed, and the other of two three-hinged arch ribs. On Plate LXXV are shown cross-sections of these bridges. The stresses in the arches of these two bridges are about the same;



CONCRETE BRIDGES.
MISCELLANEOUS DETAILS.

that in the fixed arch, however, runs up to almost 10% more than that in the other near the springing line.

The stress from the temperature in the fixed arch here shown is in some places 40% of the total, assuming a rise and fall of 40° Fahr. from the mean temperature. An additional objection to the fixed arch is the uncertainty of temperature stresses. Conservative engineers generally assume a variation of 40° Fahr. each way from the mean. Some, however, assume a total variation of 40 degrees. The writers do not believe this to be good practice, for the reason that the time of the construction of the arches cannot be specified, therefore some may be built in quite cold weather, and others when the weather is warm. In the Rye Outlet Bridge, for example, the first arch was poured in April, when the average temperature was about 50 degrees. This arch, therefore, probably has a variation of about 40° each way from the setting temperature. The last arch was poured about July 1st, when the average temperature was more than 70 degrees. As concrete sets at a temperature several degrees above that of the surrounding air, the probable maximum drop in temperature below that of setting will be about 65 degrees. The other arches range between these two, all of them, probably, having a greater fall than rise. This uncertainty cannot be guarded against, as it is manifestly impossible to specify at just what time of the year the arches shall be constructed. If a bridge is safeguarded against this uncertainty by designing the arches for a variation of 60° each way from the setting temperature, it greatly increases the cost, and renders the three-hinged arch still more economical in comparison.

Fig. 3 shows a fixed and a three-hinged arch. Their construction, with the exception of the arch, is the same. On Plate LXXV there is shown a cast-steel hinge for the three-hinged arch, similar to those used in the Traver Hollow Bridge now being built by the New York Board of Water Supply. On Plate LXXV is shown a granite hinge. The cost of the steel in the hinge would be about 6 cents per lb., and of the bronze pin and lining about 30 cents per lb. The cost of the granite would be about $50 per cu. yd. and the lead about 8 cents per lb. The cost of the concrete for the Rye Outlet Bridge would be about $12.50 per cu. yd. The quantity of concrete in the fixed arch span on Fig. 3 is 380 cu. yd.; that in the three-hinged arch is 200 cu. yd. The difference in cost of the two bridges, therefore, would be as follows:

WITH METAL HINGES.

Fixed arch, excess in concrete, 180 cu. yd. at $12.50		$2 250
Three-hinged arch, steel hinges, 11 000 lb. steel at 6 cents	$660	
Three-hinged arch, bronze pin, etc., 600 lb. bronze at 30 cents	180	
	——	840
Difference in favor of the three-hinged arch		$1 410

WITH GRANITE HINGES.

Fixed arch, excess in concrete, 180 cu. yd. at $12.50		$2 250
Three-hinged arch, granite hinge, 9 cu. yd. at $50	$450	
Three-hinged arch, sheet lead, 600 lb. at 8 cents	48	
	——	498
Difference in favor of the three-hinged arch		$1 752

The ribs of this arch are rather too wide for a stone hinge, as it is not good practice to cut a thin stone 9 ft. in length, and it is not desirable to have a joint in the hinge. If the arch rib is wider than 6 or 7 ft., it is better to use a metal hinge; if it is of less width, a stone hinge may be used with advantage, as it is very simple and economical.

When the arch span is 200 ft. or more there is a decided economy in making the rib of I-section instead of rectangular. By building the rib of this section there is a gain in two ways. A portion of the concrete is taken from along the neutral axis of the arch, where it does the minimum amount of good, and a portion of it is replaced along the upper and lower edges of the rib as flanges, where it will act to much greater advantage. These flanges should not project very far, and the slopes connecting them with the web should be quite steep, so that there will be no difficulty in filling the flanges completely with concrete. The web should be left sufficiently wide to contain two steel ribs, with room between them in which the men may move about in placing and ramming the concrete. This makes the minimum satisfactory thickness of the web about 3 ft. The flanges should not project more than 12 or 15 in. from the web, therefore, with a 3-ft. web, the width of the rib would not be more than 5 or 5½ ft.

The analysis of the rib of I-section is just as simple as that of

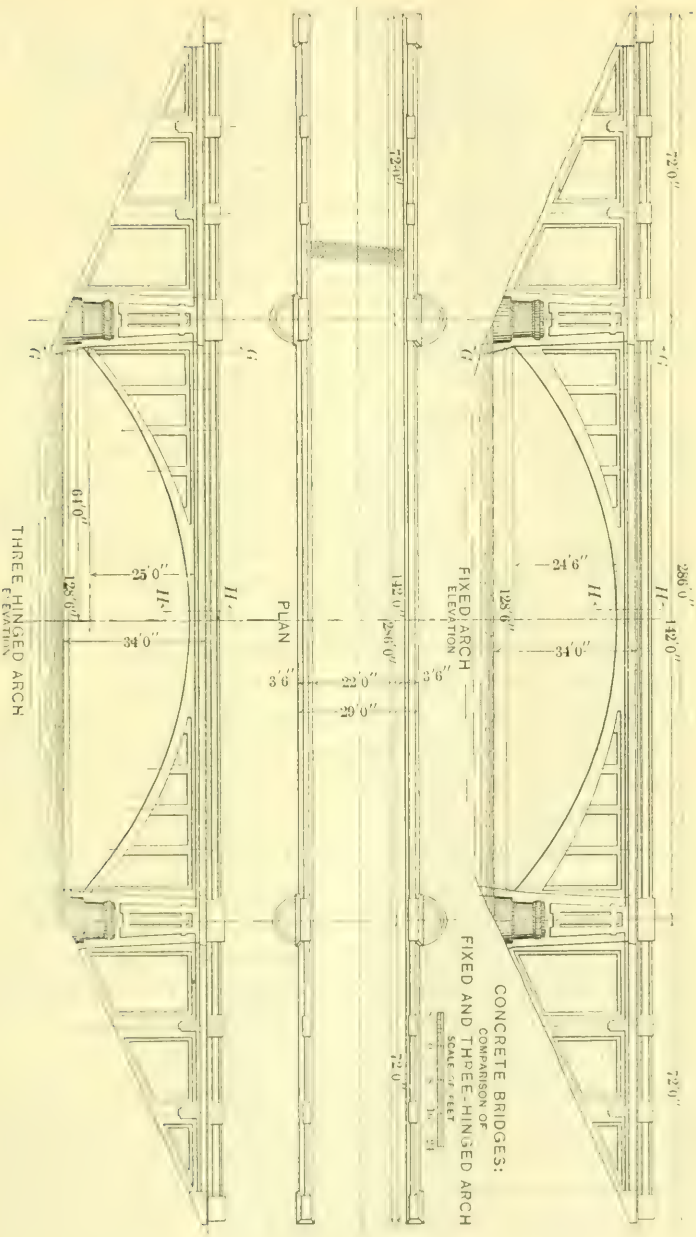

THREE HINGED ARCH
ELEVATION
PLAN
FIXED ARCH
ELEVATION
CONCRETE BRIDGES:
COMPARISON OF
FIXED AND THREE-HINGED ARCH
SCALE OF FEET
72′0″
142′0″
286′0″
128′6″
64′0″
25′0″
24′6″
34′0″
3′6″
22′0″
29′0″

Fig. 3.

rectangular section, except in computing the stress in the outer fibers. On account of the moment of inertia of the I-section being more complicated than that of the simple rectangle, the process of computing the stress at the joints is longer and more tedious.

On Fig. 4 are shown two three-hinged arch bridges with ribs of the same width. In one the ribs are of I-section, and in the other the section is rectangular. The ribs are designed so that the stress in the outer fibers is the same in both cases. The portion of the structure above the arch is the same in each of the bridges. In the arch of the bridge with ribs of I-section there are 420 cu. yd. of concrete; and in the other there are 490 cu. yd. Thus there is a saving of 70 cu. yd. of concrete in the arch of I-section over the other. There will also be a slight saving in the hinges, as the thrust thereon is materially less on account of the concrete in each rib having been reduced 35 cu. yd., or 140 000 lb. There will also be a slight saving in the abutments, due to the same cause. However, neglecting entirely the saving in the two latter cases, the sum saved by building the ribs of I-section is more than $800 for the single span.

The question might be asked: why would it not be better to increase the depth and decrease the width of the rectangular rib, making it as small in area as the I-section, without overstressing it?

The objection to doing this is that the ribs have to be braced at certain intervals; and between the point of attachment of these braces they act as struts. A strut, to be economically designed, should be equally strong in all directions. If the rib, therefore, should be built three or four times deeper than wide, it would be much weaker, acting as a strut, unless the bracing was put in at shorter intervals; the increase in concrete, due to the additional bracing, would counterbalance the saving in the rib, and nothing would be gained thereby; and the arch will not have been as well designed. The bracing was not considered in the comparison of the arches, it being assumed as the same in both cases, as the ribs are of the same width.

Another and most important point in the design of a concrete arch bridge is the shape of the piers. Following out the same idea as in the arch, that is, to get as much of the concrete as possible placed well away from the neutral axis, it is very desirable to build the piers, from a short distance below the springing line, in two separate legs, braced at whatever intervals may be necessary, or, in extreme cases,

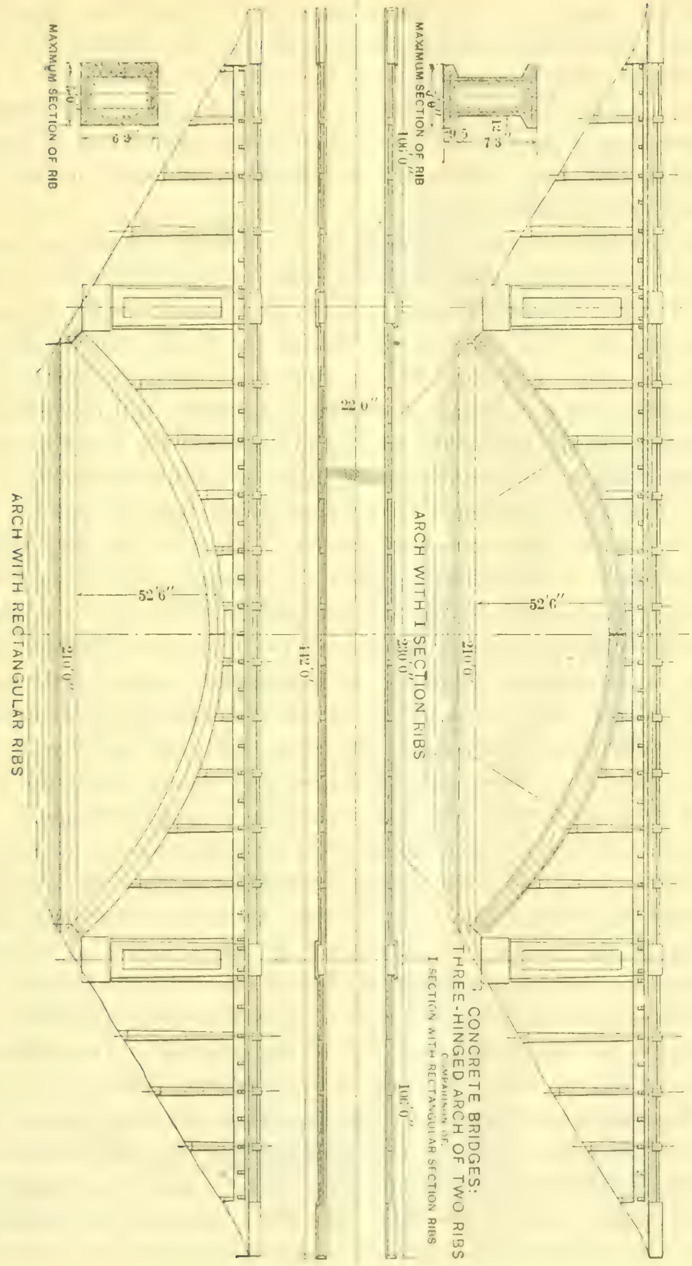

MAXIMUM SECTION OF RIB
MAXIMUM SECTION OF RIB
ARCH WITH RECTANGULAR RIBS
ARCH WITH I SECTION RIBS
CONCRETE BRIDGES:
THREE-HINGED ARCH OF TWO RIBS
I SECTION WITH RECTANGULAR SECTION RIBS
52'6"
52'6"
22'0"
142'0'

FIG. 4.

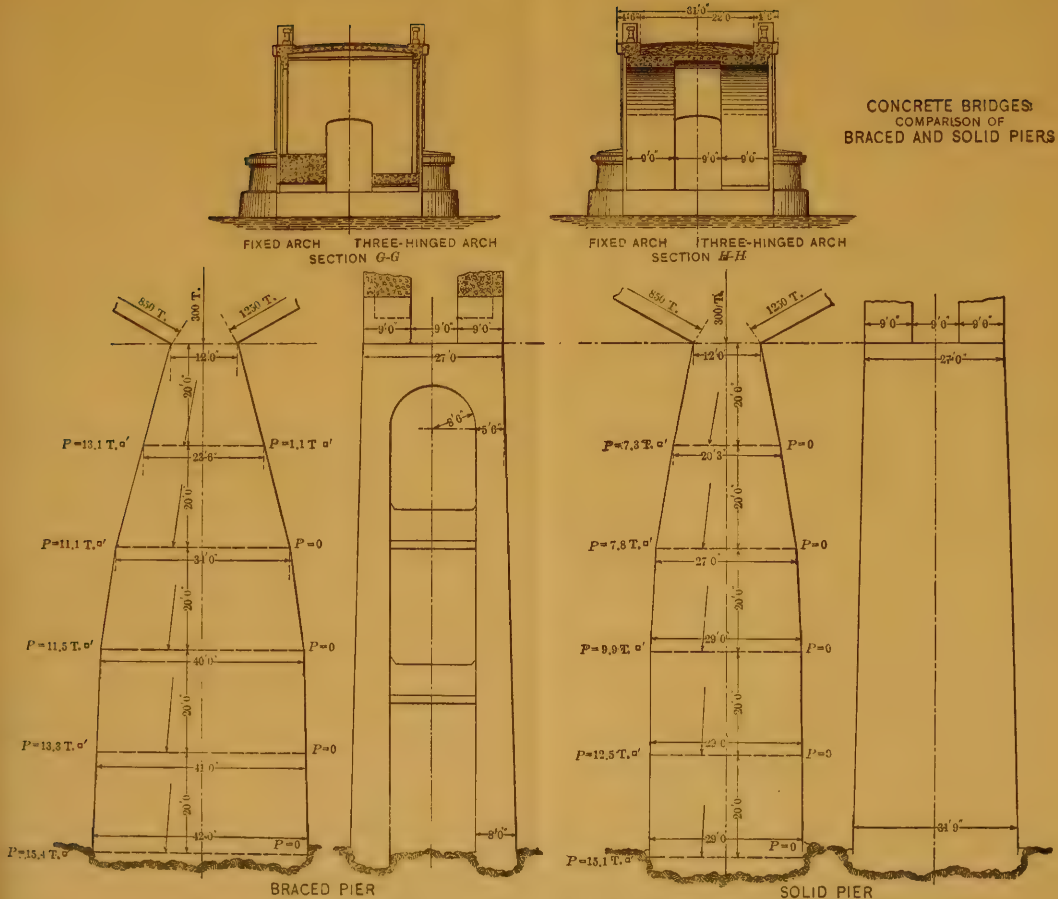
connecting them by a thin diaphragm down to where they enter the ground. These legs should be made as thin as the nature of the case will allow, in direction transverse to the axis of the bridge; but, in the direction of the axis of the bridge, they should thicken as required in order to keep the point of application of the resultant of all forces, acting on any joint, within the middle third, and also to keep the stress within the desired limits.

In a rectangular pier, generally, if it is desired to keep the line of pressure within the middle third, the stress will not be nearly as great as it is proper to allow, and yet it is not good practice to let the point of application of the resultant lie outside the middle third, and thus cause tension in the joint. On the other hand, with the braced pier, one is able, with a little care, to design a pier which will have the line of pressure within the middle third, and also have the stress at about the figure desired, thereby obtaining a pier of maximum economy.

On Plate LXXVI there are two piers illustrating this point. The first is a braced pier somewhat similar to those in the Rye Outlet Bridge. From a short distance below the springing line the pier consists of two separate legs, braced at two points. This pier is of about the same height as two of the piers of the Rye Outlet Bridge. The second is an ordinary solid pier of rectangular section of the same height. Both piers are designed so that the pressure line cuts the middle third point of all joints. On comparing these two piers it will be seen that the stresses in the braced pier remain quite uniform, except near the bottom, where they increase a moderate amount. In the upper part of the rectangular pier, however, the stresses are too low for economy, and yet it is not desirable to increase the stress by allowing the pressure line to go outside the middle third, and cause tension in the joints. The difference in the quantity of material in these two piers is surprising; the braced pier has only 1 785 cu. yd. of concrete; the solid pier has 2 825 cu. yd., a difference of 1 040 cu. yd., or 58% of the braced pier, and 37% of the solid pier. The difference in cost of the two piers, therefore, is about $6 000. The braces in the pier, however, are of reinforced concrete, which tends to decrease the difference somewhat; but, on the other hand, if the earth excavation is deep, and within a coffer-dam, there will be much less excavation for the braced than for the solid pier, which increases the difference in the cost. Piers of this shape are not handsome, but if economy is

PLATE LXXVI.
PAPERS, AM. SOC. C. E.
AUGUST, 1913.
SMITH ON
CONCRETE BRIDGES.

CONCRETE BRIDGES:
COMPARISON OF
BRACED AND SOLID PIERS



an important consideration, they are very desirable; and if they are to be hidden by the water from a short distance below the springing line, as in the Rye Outlet Bridge, they will not detract from the appearance.

This type of pier is especially economical for a bridge in running water in which there is likely to be heavy blocks of ice or logs of wood moving rapidly. By putting a cut-water on the up-stream side to deflect such objects, and spreading the legs of the pier rapidly and connecting them with a thin diaphragm, the bridge can be braced thoroughly with very little additional masonry in the piers. In a very cold climate, where heavy ice is likely to form about the piers, the connecting diaphragm should contain steel reinforcement.

In all the bridges on the accompanying illustrations the width is the same; therefore a comparison of the quantity of concrete per linear foot of arch gives a fair idea of the economy of the arches alone. The quantity of arch concrete per linear foot of span in each of the bridges shown is as follows:

Fig. 3, fixed arch, ribs 9 ft. wide........................	3.00 cu. yd.
Fig. 3, three-hinged arch, ribs 9 ft. wide...............	1.57 " "
Fig. 4, three-hinged arch, rectangular ribs, 5 ft. wide...	2.33 " "
Fig. 4, three-hinged arch, I-section ribs, 5 ft. wide.....	2.00 " "

From this it is seen that, with the narrow ribs, although the abutments are 50% farther apart, there is very little more concrete per linear foot than in the shorter three-hinged arch with ribs 9 ft. wide.

The writers think that the following conclusions are amply justified by the foregoing comparative investigations:

First, that an arch span consisting of two separate ribs is more economical than one with a solid soffit, if the span is greater than 100 ft.

Second, that narrow, deep ribs are more economical than thin, wide ones.

Third, that the three-hinged arch is more economical and reliable than fixed or two-hinged arches for spans greater than 100 ft.

Fourth, that for spans of 200 ft. or more, the rib of I-section is more economical than the rectangular rib.

Fifth, that piers of any considerable height are much more econom-

ical if built of two separate legs thoroughly braced, thickening rapidly in the direction of the axis of the bridge as they go down.

All numerical computations have been omitted herein, as all the processes of investigation are simple, and it was not desired to lengthen the paper by including them.

The ratio of the modulus of elasticity of steel to concrete was taken as 15, and in obtaining the moment of inertia of the sections at the various joints the steel was considered as being replaced by 15 times its area of concrete.

The Rye Outlet and Traver Hollow Bridges were constructed by the Board of Water Supply, consisting of Messrs. Charles Straus, Charles N. Chadwick, and John F. Galvin. J. Waldo Smith, M. Am. Soc. C. E., is Chief Engineer and A. D. Flinn, M. Am. Soc. C. E., Department Engineer, Headquarters Department, in charge of all design. Charles E. Gregory, M. Am. Soc. C. E., was Designing Engineer in Charge of Design of Dams and Bridges, and the writers had charge of the design of the Rye Outlet Bridge and the preliminary design of the Traver Hollow Bridge under Mr. Gregory.

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A RATIONAL FORMULA FOR ASPHALT STREET SURFACES.*

By J. Alden Griffin, Assoc. M. Am. Soc. C. E.

Every now and then the question is raised: "What is the proper crown to give an asphalt street?" and there is a discussion as to which of the many formulas of to-day gives the best results.

Having been asked this question many times in the past few years, and especially while connected with municipal improvements in Los Angeles, Cal., the writer has given the matter careful investigation, and, by a comparison of the surfaces proposed by the various formulas, has arrived at the conclusion that the crown rise should vary with the cross-fall as well as the grade of the roadway, and that a crown considerably lower than that proposed by the well-known formula of the late Andrew Rosewater, M. Am. Soc. C. E., should be used on streets having a cross-fall between the gutter grades. The writer even favors one which is slightly lower, where there is no cross-fall in the roadway; and, having reached these conclusions, he proceeded to determine the proper amount of reduction to make in the crown for varying cross-falls. After a great many experiments he adopted the following modification of Mr. Rosewater's formula. This gives the best results,

*This paper will not be presented at any meeting, but written communications on the subject are invited for publication with it in *Transactions*.

using one-eighth of the cross-fall plus $\frac{3}{4}$ in. as the reduction factor, but some may wish to change $0.12H$ in the formula to $0.10H$, or even $0.08H$, in order not to reduce the crown quite so much; however, the following is recommended:

$$C = \frac{W\,(100 - 4\,p)}{5\,000} - (0.12H + 0.06)$$

in which W = the width of the roadway between curbs, in feet; p = the percentage of grade longitudinally on the street; H = the cross-fall of the street, or the difference of elevation between the high and low gutters, in feet; and C = the height of the crown above the mean gutter grade, in feet.

TABLE 1.

Width of roadway, in feet.	Percentage of grade on street.	Crown, with no cross-fall.	Crown Rise, for Variable Cross-Falls, in Feet.											
			0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00
28	1	0.48	0.45	0.42	0.39	0.36	0.33	0.30	....	....	....	....	....	....
28	2	0.45	0.42	0.39	0.36	0.33	0.30	0.27	....	....	....	....	....	....
28	3	0.43	0.40	0.37	0.34	0.31	0.28	0.25	....	....	....	....	....	....
28	4	0.41	0.38	0.35	0.32	0.29	0.26	0.23	....	....	....	....	....	....
28	5	0.39	0.36	0.33	0.30	0.27	0.24	0.21	....	....	....	....	....	....
34	1	0.59	0.56	0.53	0.50	0.47	0.44	0.41	0.38	....	....	....	....	....
34	2	0.57	0.54	0.51	0.48	0.45	0.42	0.39	0.36	....	....	....	....	....
34	3	0.54	0.51	0.48	0.45	0.42	0.39	0.36	0.33	....	....	....	....	....
34	4	0.51	0.48	0.45	0.42	0.39	0.36	0.33	0.30	....	....	....	....	....
34	5	0.48	0.45	0.42	0.39	0.36	0.33	0.30	0.27	....	....	....	....	....
40	1	0.71	0.68	0.65	0.62	0.59	0.56	0.53	0.50	0.47	....	....	....	....
40	2	0.68	0.65	0.62	0.59	0.56	0.53	0.50	0.47	0.44	....	....	....	....
40	3	0.64	0.61	0.58	0.55	0.52	0.49	0.46	0.43	0.40	....	....	....	....
40	4	0.61	0.58	0.55	0.52	0.49	0.46	0.43	0.40	0.37	....	....	....	....
40	5	0.58	0.55	0.52	0.49	0.46	0.43	0.40	0.37	0.34	....	....	....	....
46	1	0.82	0.79	0.76	0.73	0.70	0.67	0.64	0.61	0.58	0.55	....	....	....
46	2	0.79	0.76	0.73	0.70	0.67	0.64	0.61	0.58	0.55	0.52	....	....	....
46	3	0.75	0.72	0.69	0.66	0.63	0.60	0.57	0.54	0.51	0.48	....	....	....
46	4	0.71	0.68	0.65	0.62	0.59	0.56	0.53	0.50	0.47	0.44	....	....	....
46	5	0.68	0.65	0.62	0.59	0.56	0.53	0.50	0.47	0.44	0.41	....	....	....
56	1	1.01	0.98	0.95	0.92	0.89	0.86	0.83	0.80	0.77	0.74	0.71	....	....
56	2	0.97	0.94	0.91	0.88	0.85	0.82	0.79	0.76	0.73	0.70	0.67	....	....
56	3	0.93	0.90	0.87	0.84	0.81	0.78	0.75	0.72	0.69	0.66	0.63	....	....
56	4	0.88	0.85	0.82	0.79	0.76	0.73	0.70	0.67	0.64	0.61	0.58	....	....
56	5	0.84	0.81	0.78	0.75	0.72	0.69	0.66	0.63	0.60	0.57	0.54	....	....
62	1	1.13	1.10	1.07	1.04	1.01	0.98	0.95	0.92	0.89	0.86	0.83	0.80	....
62	2	1.08	1.05	1.02	0.99	0.96	0.93	0.90	0.87	0.84	0.81	0.78	0.75	....
62	3	1.03	1.00	0.97	0.94	0.91	0.88	0.85	0.82	0.79	0.76	0.73	0.70	....
62	4	0.98	0.95	0.92	0.89	0.86	0.83	0.80	0.77	0.74	0.71	0.68	0.65	....
62	5	0.93	0.90	0.87	0.84	0.81	0.78	0.75	0.72	0.69	0.66	0.63	0.60	....
72	1	1.32	1.29	1.26	1.23	1.20	1.17	1.14	1.11	1.08	1.05	1.02	0.99	0.96
72	2	1.27	1.24	1.21	1.18	1.15	1.12	1.09	1.06	1.03	1.00	0.97	0.94	0.91
72	3	1.21	1.18	1.15	1.12	1.09	1.06	1.03	1.00	0.97	0.94	0.91	0.88	0.85
72	4	1.15	1.12	1.09	1.06	1.03	1.00	0.97	0.94	0.91	0.88	0.85	0.82	0.79
72	5	1.09	1.06	1.03	1.00	0.97	0.94	0.91	0.88	0.85	0.82	0.79	0.76	0.73

It will be noticed that on a roadway having a very steep cross-fall the upper gutter will not hold water, which, in the majority of such extreme cases, will do no harm, and will very often save a cross-gutter at the intersection; however, it may be desired at some time to hold the water in the upper gutter, and this may be accomplished, without increasing the side slope of the surface, by shifting the crown to the

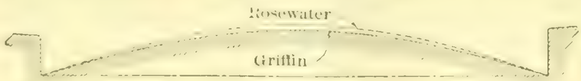

Fig. 1

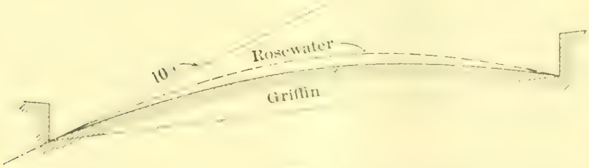

Fig. 2.

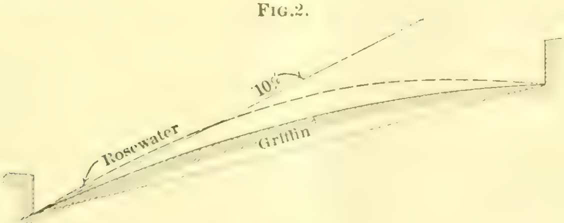

Fig. 3.

Fig. 4.

upper side of the center of the roadway as shown in Fig. 4, which indicates a special cross-section at that point.

Table 1 is compiled from the formula for the more common roadway widths in Los Angeles.

Figs. 1 to 4 illustrate the comparison between Mr. Rosewater's formula and the modification herein proposed on a 40-ft. roadway

having a 1% grade. Fig. 1 is for no cross-fall; Fig. 2 for a cross-fall of 1 ft. between the mean gutters, and Fig. 3 is an extreme case with a cross-fall of 2 ft. between the mean gutters. Fig. 4 illustrates a section in which the lower half meets the formula and the upper half is modified to hold the water in the upper gutter.

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DERIVATION OF RUN-OFF FROM RAINFALL DATA.*

By Joel D. Justin, Assoc. M. Am. Soc. C. E.

In the study of a drainage basin which is to be utilized for water supply or water power, it frequently happens that there is a dearth or utter lack of run-off data, though more or less precipitation data are almost always available.

It was with the desire of finding out if it were not possible to develop some rational method of deriving run-off from rainfall data on various water-sheds, that the present study was undertaken.

The quantity of rainfall appearing as run-off on any water-shed is governed by many conditions, chief among which are character of vegetation, extent of forest covering, prevailing winds, relative humidity of atmosphere, barometric pressure, percentage of water surface, geology of basin, slope, and mean annual temperature.

Before investigating the manner in which the relations between rainfall and run-off differ on various water-sheds, the writer will examine into the manner in which they vary from year to year on any one water-shed.

The late George W. Rafter, M. Am. Soc. C. E., showed in his paper, "The Relation of Rainfall to Run-off,"† that the relation of rainfall

*This paper will not be presented at any meeting, but written communications on the subject are invited for publication with it in *Transactions*.

† Geological Survey, Water Supply Paper No. 80.

to run-off on a water-shed could often be expressed as an exponential equation. For the Upper Hudson he gives the two equations, $P^2 = 84.5\ R$ and $P^{1.77} = 34.3\ R$; P being the annual precipitation and R the annual run-off, in inches, on the water-shed. He does not, however, suggest any constant value for the exponent of P or R for other water-sheds.

After plotting many rainfall and run-off data, the writer became convinced that the relations between rainfall and run-off on almost every water-shed could be expressed by a logarithmic equation, of the form, $C = K\ R^n$, in which C = annual run-off, R = annual rainfall, K is an abstract number, constant for any one water-shed, and n is an exponent constant for the water-shed.

In solving the equations it was found that n always came out nearly equal to 2; hence it was chosen as a constant for all water-sheds and always equal to 2.

The writer then plotted, on logarithmic cross-section paper, using annual run-off in inches as ordinates and annual rainfall in inches as abscissas, a considerable portion of the available reliable data. He found that on all these water-sheds the relation may be well expressed by the formula:

$$C = KR^2,$$

in which C is the annual run-off, in inches; R is the annual rainfall, in inches; and K is a constant which is different for each water-shed, and has a value depending on those conditions which make the relations between rainfall and run-off on one water-shed different from those on another.

Most hydrologists in America choose December 1st as the beginning and ending of the water year; others use October 1st, and in England September 1st is the date selected, the object, of course, being to choose a time when the ground-water conditions will be more likely to be the same from year to year.

In the accompanying diagrams, both October 1st and December 1st, have been used, the date for beginning and closing the water year being stated in each case.

Accuracy of Data.—The accuracy of existing data does not justify precision. On some of the territories for which diagrams are presented (Figs. 1 to 19) there is one rainfall station per 1 000 sq. miles of water-shed. In the computation of run-off, a discrepancy of 1 or

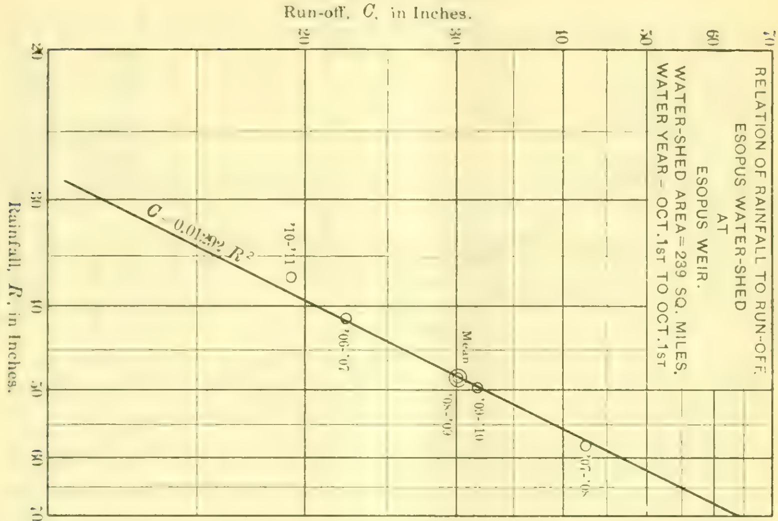


Fig. 1.

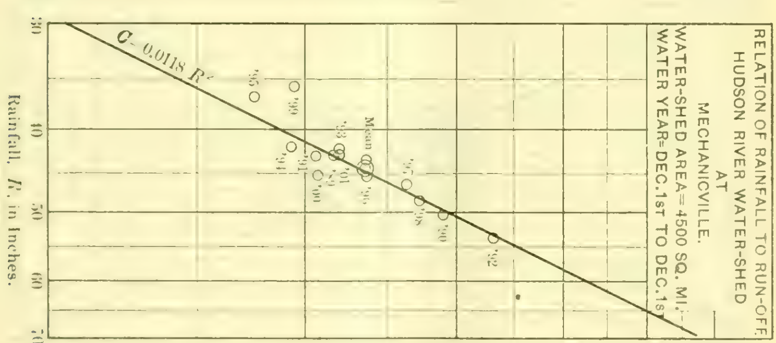


Fig. 2.

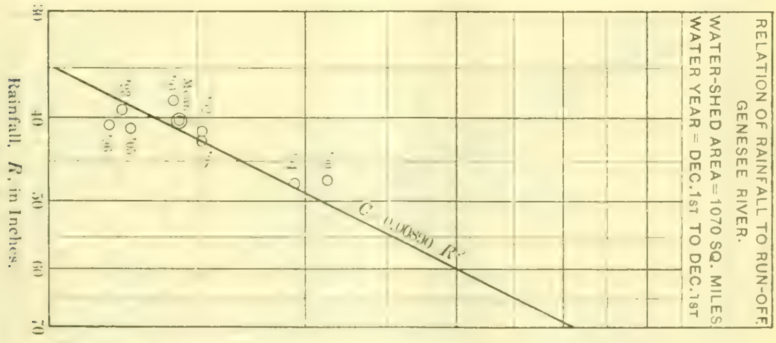


Fig. 3.

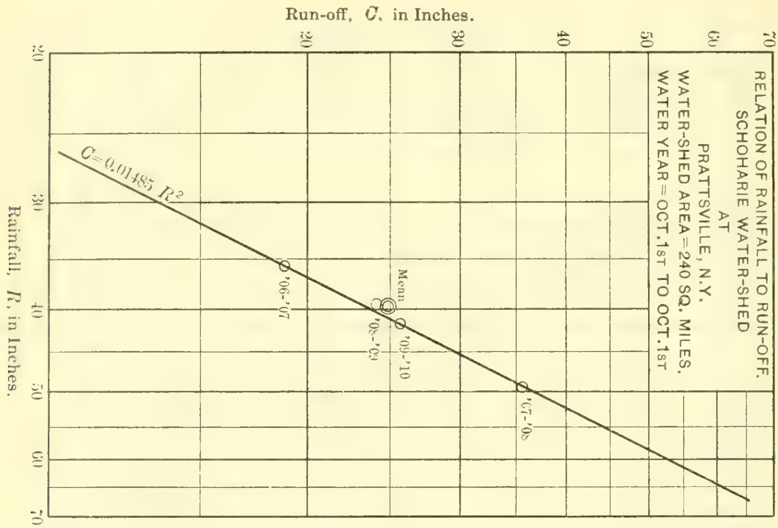


FIG. 4.

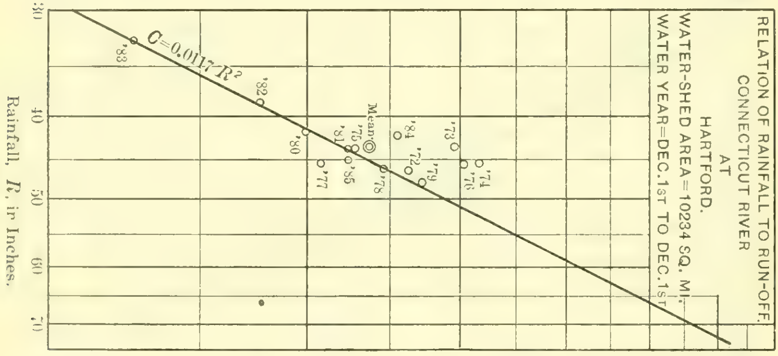


FIG. 5.

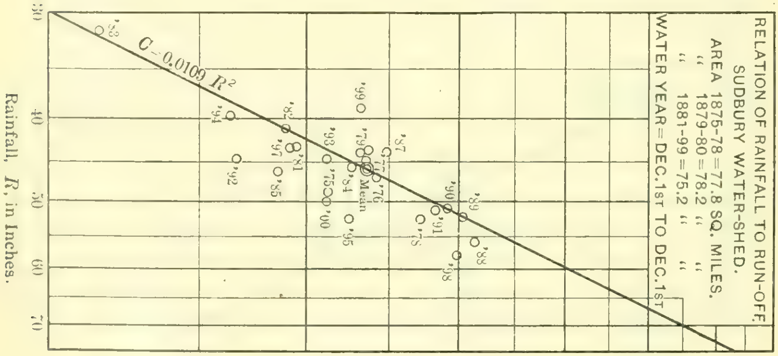


FIG. 6.

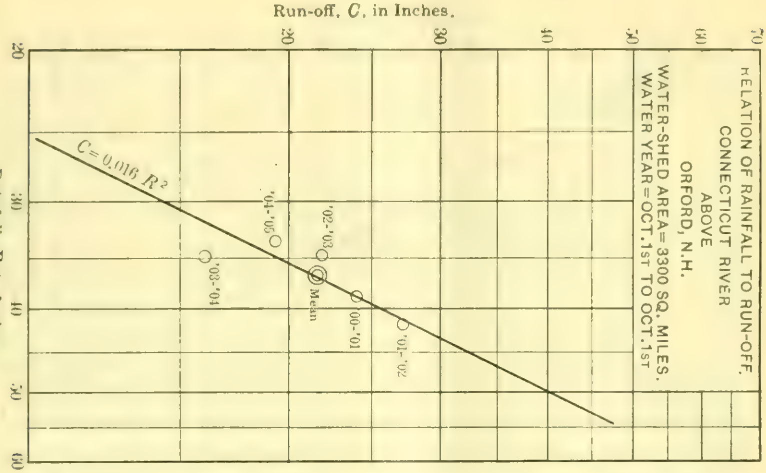


Fig. 7.

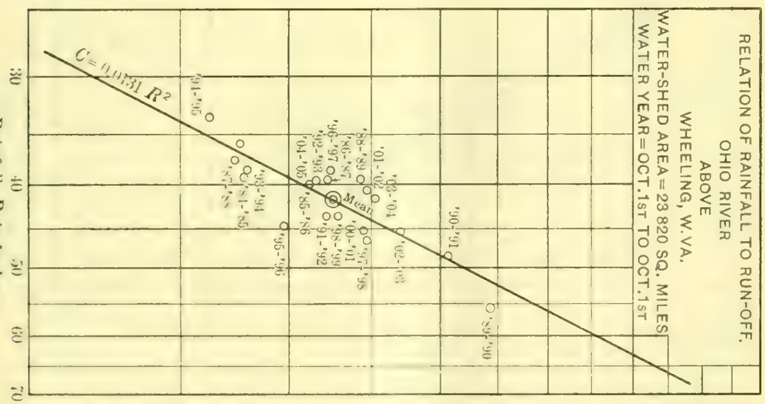


Fig. 8.

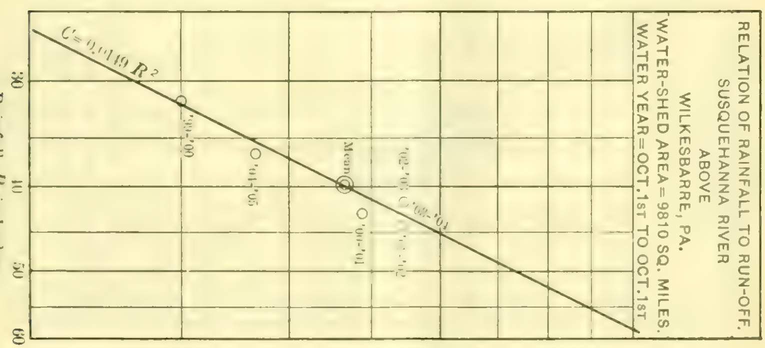
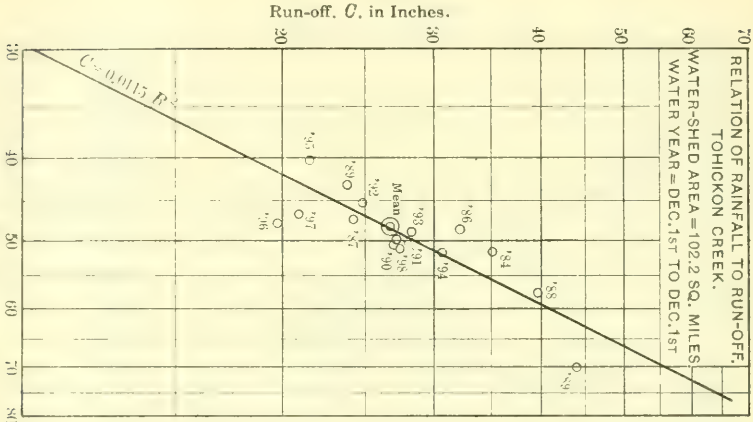
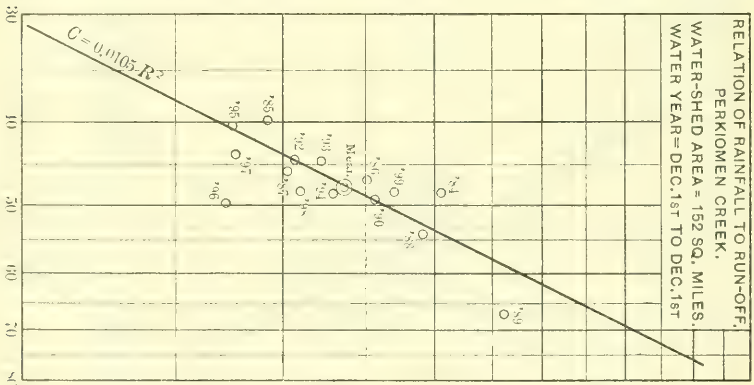


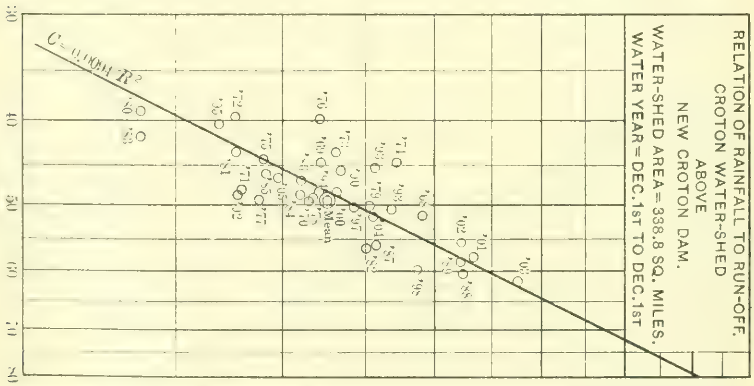
Fig. 9.



Rainfall, R, in Inches.
FIG. 10.



Rainfall, R, in Inches.
FIG. 11.



Rainfall, R, in Inches.
FIG. 12.

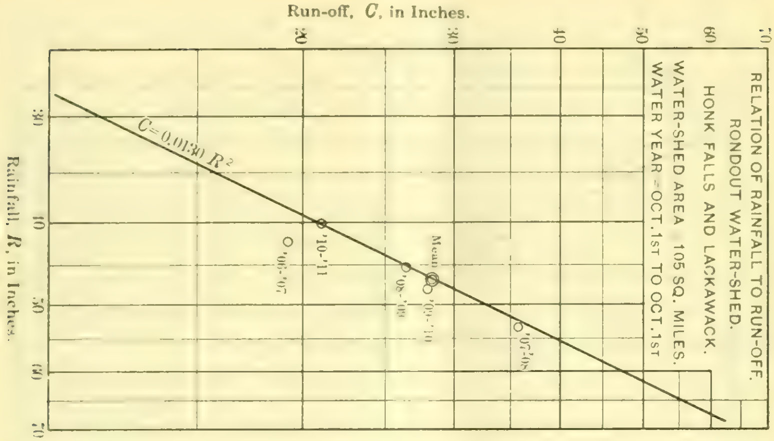


Fig. 13.

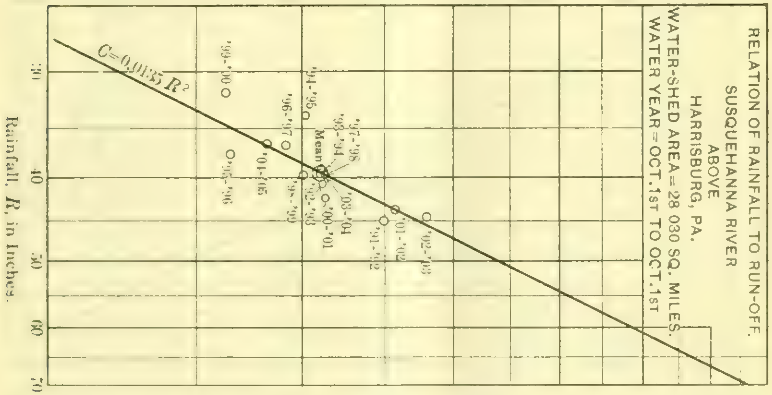


Fig. 14.

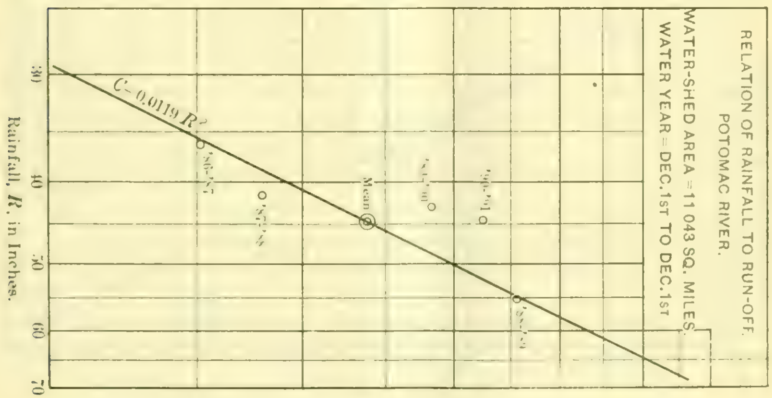


Fig. 15.

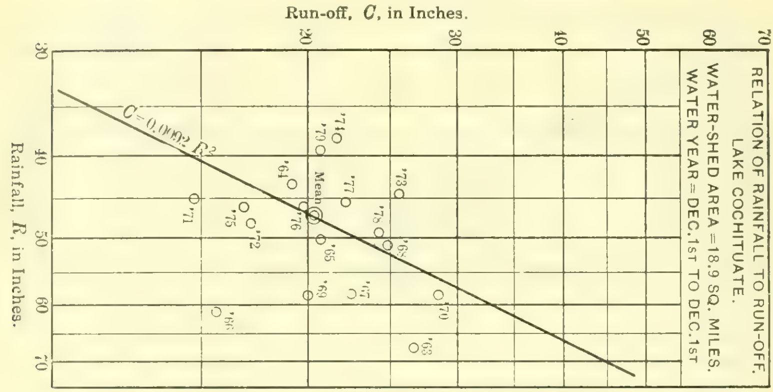


FIG. 16.

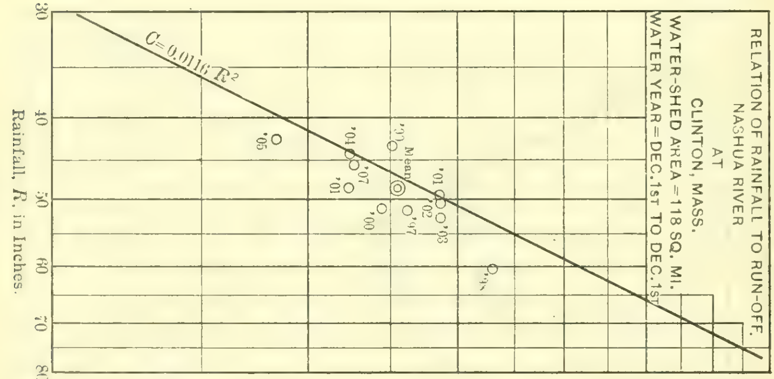


FIG. 17.

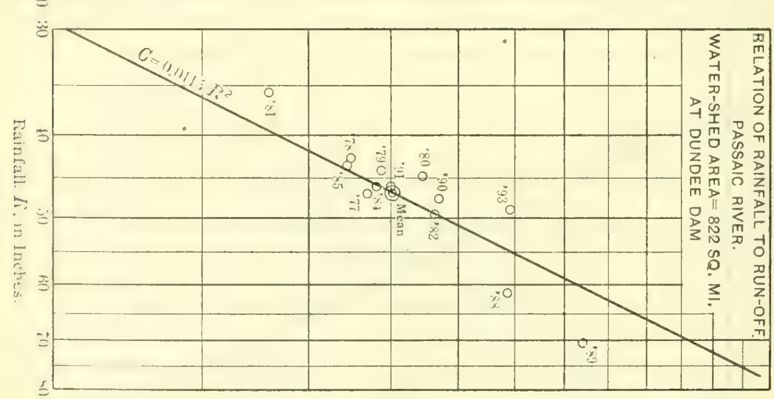


FIG. 18.

2 in. is not worthy of discussion. In most cases one can safely assume a probable error of 10% in the observed rainfall for any one year for most water-sheds. The error in any individual record at a certain station is undoubtedly less than this in most cases, but when several rainfall stations are combined to give the rainfall for an entire water-shed, the probable error is increased. In general, the larger the number of rainfall stations on a water-shed the less the probable error.

Run-off records are usually more accurate; but, up to a few years ago, few streams were accurately gauged, and the error was generally positive. At present many of the records of the Water Resources Branch of the United States Geological Survey and of many municipal water supplies, are all that could be desired; the probable error not exceeding 5 per cent. Perhaps one of the most accurate records, for purposes of comparison between rainfall and run-off, is that on the Esopus water-shed (area 239 sq. miles) of the Catskill water supply system of New York City. On this water-shed there have been maintained from 8 to 13 well-distributed rainfall stations. The measurement of run-off has been made at a concrete weir, especially built for the purpose, with a cross-section corresponding to one of the models used in extensive experiments at the Cornell University Hydraulic Laboratory, described in Water Supply Paper No. 200, of the U. S. Geological Survey.

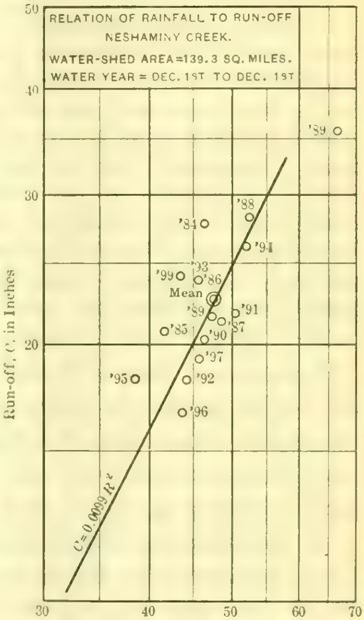


FIG. 19.

The relation between rainfall and run-off on this water-shed is shown in Fig. 1. It will be noted that all the points fall almost precisely on the curve, $C = 0.01292 R^2$.

When rainfall and run-off data are plotted on diagrams, such as those presented, the probable error in using the resulting curves in mass-curve storage studies is much reduced.

Effect of Proportion of Water Surface.—The writer believes that many hydrologists have exaggerated the importance of the effect of water surfaces on a water-shed in decreasing the quantity of run-off. Aside from regulating the distribution of the run-off throughout the year, the effect of any ordinary proportion of water surface is so small as to be negligible.

This is well shown by Mr. Rafter.* In discussing the percentage of water surface on the Croton water-shed (3.56%) he says:

"It may at first thought be imagined that these large water surfaces exposed to evaporation have considerably increased the ground evaporation over the entire catchment. When, however, one considers that it is only the difference between what a water-surface evaporation and what a ground-surface evaporation would be, the difference is seen to be not very much. For instance, assuming the water-surface evaporation at 36 inches per year and the ground-surface evaporation at 27 inches per year, the difference becomes 9 inches. With 12 square miles of water surface in 1900, giving 3.56 per cent. of the whole, the excess of water-surface evaporation over ground-surface evaporation is 0.32 of an inch, a quantity which is so far within the limit of possible error in other directions as to be negligible."

Grouping of Data by Water Years.—In the comparison of rainfall and run-off grouped by water years, beginning October 1st, December 1st, or some other date, it is frequently observed that, on any water-shed, certain years, having the same recorded rainfall, have recorded run-off differing by from 1 to 4 in.

In the diagrams, although most of the points fall on or near the curves represented by the equation, $C = K\ R^2$, there are some which are at some distance from the curves. Noting this condition, many claim it as proof that there is no definite relation between rainfall and run-off. In reality, the apparent discrepancy is due merely to variation from year to year in ground-water conditions on the date arbitrarily assumed for beginning the water year. The fact that a point does not fall on the curve, does not necessarily show that the observations are at fault, but in most cases it does indicate that the date of beginning the water year assumed for the water-shed is not the true one for that particular year.

It is an error to consider the water year as a hard and fast division of time. Many of the points, which in the diagrams plot some distance from that curve, would fall directly on or very near it, had

* "The Relation of Rainfall to Run-off."

the first of the preceding or succeeding month been used for beginning the water year.

The true water year does not begin or end at any particular date, but should be regulated so that ground-water conditions are nearly constant on the dates selected for the beginning of such years. It is believed that, if this could be done, all points for which the data are accurate would fall on or near the curve represented by the equation, $C = K R^2$.

Owing, however, to the almost utter lack of data on ground-water levels, it is impracticable to adopt this method of division. Especially in the study of large storage propositions, the apparent discrepancies will balance each other, and will not affect the conclusions.

Manner in Which the Relations Between Rainfall and Run-off Vary from One Water-shed to Another.—It has frequently been observed that, other things being equal, a steep water-shed will have a greater run-off for the same rainfall than a flat one. The water, staying on the water-shed a shorter length of time, has less chance to evaporate. Mr. Vermeule has shown successfully the great influence which the mean annual temperature of a water-shed has on the relation of rainfall to run-off.

These two elements, slope and mean annual temperature, the writer believes, are, in general, the chief factors determining the manner in which the relation between rainfall and run-off vary from one watershed to another. Hence he will use them in determining the value of K.

The slope of a water-shed may be defined as the difference in elevation between the highest and lowest points divided by the square root of the area.

The proper value for the mean annual temperature of a watershed can generally be determined by a study of the data published by the United States Weather Bureau in the "Summary of Climatological Data for the United States, by Sections." In using these data, it sometimes happens, especially on mountainous water-sheds, that all the observations are at stations in the valleys. On such a water-shed the mean annual temperature frequently varies directly with the elevation. In such a case, a practical method of determining the mean annual temperature would be as follows:

(1) Take the average temperature at the stations;

(2) The average elevation for the same stations;

(3) The average elevation of the water-shed = the elevation of the highest point plus the elevation of the lowest, divided by 2;

(4) Take the difference between the average elevation of the stations and the average elevation of the water-shed;

(5) Multiply this by the mean difference in temperature per foot of increase in elevation;

(6) Finally, subtracting this from the average temperature at the stations will give the mean annual temperature of the water-shed.

TABLE 1.—VALUES OF K, T, S, AND KT, FOR VARIOUS WATER-SHEDS.

Water-shed.	K in the formula, $C = KR^2$.	T. Mean annual temperature.	S. Slope of water-shed.	$KT = K \times T$.
Lake Cochituate	0.0092	48.5	0.0116	0.446
Sudbury	0.0109	46.0	0.0119	0.501
Hudson	0.0118	41.9	0.0149	0.494
Rondout	0.0130	47.0	0.0664	0.611
Croton	0.0094	49.0	0.0110	0.460
Esopus	0.01292	44.5	0.0468	0.575
Passaic	0.0115	48.4	0.00977	0.555
Genesee	0.0089	45.5	0.00554	0.405
Neshaminy	0.0099	50.6	0.0101	0.500
Perkiomen	0.0105	48.6	0.0148	0.511
Tohickon	0.0115	49.6	0.0166	0.571
Nashua	0.0116	45.0	0.0278	0.522
Connecticut	0.0117	42.0	0.0117	0.490
Schoharie	0.01485	42.3	0.0367	0.630

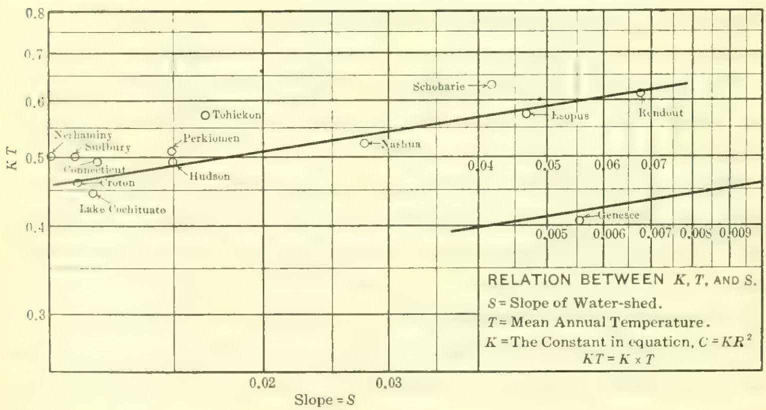


FIG. 20.

In Fig. 20, T is the mean annual temperature, S is the slope of the water-shed, determined as previously described, and K is the constant in the equation, $C = K R^2$.

It was found that for several water-sheds having about the same value of S, K varied very nearly as the first power of T. In Fig. 20 the values of KT (the product of K and T) have been plotted as ordinates and the values of S as abscissas.

Table 1 gives the values of K, T, S, and KT, for various water-sheds.

Picking values off the logarithmic curve in Fig. 20, and solving the equation,

$$K\,T = P\,S^{x},$$

P being the unknown coefficient and x the unknown exponent, we have, for the equation of the curve, $K\,T = 0.934\,S^{0.155}$

$$\text{but } C = K\,R^2,$$

$$\text{whence } C = 0.934\,S^{0.155}\,\frac{R^2}{T},$$

which is the general formula for the relation of run-off to rainfall.

C = Annual run-off, in inches, on the water-shed;

R = Annual rainfall, in inches, on the water-shed;

S = Slope of the water-shed, equals the elevation of the highest point minus the elevation of the lowest point divided by the square root of the area;

T = Mean annual temperature of the water-shed, in degrees, Fahrenheit.

For convenience in using the formula, Table 2, giving values of $S^{0.155}$ was computed. By using this table, the formula is easily solved. Thus, for the Rondout water-shed, $T = 47$, mean $R = 46.6$, and $S = 0.0664$. From Table 2, for $S = 0.0664$, we have $S^{0.155} = 0.658$. Hence the expression for the mean annual run-off of the Rondout becomes

$$C = 0.934\,S^{0.155}\,\frac{R^2}{T} = 0.934 \times \frac{0.658 \times 2180}{47} = 28.5 \text{ in.}$$

In this case the computed mean annual run-off is just equal to the actual.

The character of the various water-sheds considered in the derivation of the formula varies widely. By reference to Table 1 it is seen that the slope and the mean annual temperature vary between wide limits. The slope of the Genesee is 0.0054, and that of the Rondout is 0.0664. The mean annual temperature of the Hudson is 41.9 and that of the Neshaminy is 50.6 degrees. In area, the variation is from 19 sq. miles for the Lake Cochituate water-shed to 10 234 sq. miles for the Connecticut at Hartford. In the matter of forestation, the variation

TABLE 2.—VALUES OF $S^{0.155}$ FOR VARIOUS VALUES OF S. TO BE USED IN SOLVING THE FORMULA, $C = 0.934\ S^{0.155}\ \frac{R^2}{T}$.

S.	$S^{0.155}$.	S.	$S^{0.155}$.	S.	$S^{0.155}$.	S.	$S^{0.155}$.	S.	$S^{0.155}$.
0.002	0.382	0.0070	0.464	0.0093	0.484	0.026	0.567	0.049	0.628
0.003	0.406	0.0071	0.465	0.0094	0.484	0.027	0.570	0.050	0.630
0.004	0.425	0.0072	0.466	0.0095	0.485	0.028	0.574	0.051	0.632
0.005	0.440	0.0073	0.467	0.0096	0.486	0.029	0.578	0.052	0.634
0.0051	0.442	0.0074	0.468	0.0097	0.487	0.030	0.582	0.053	0.636
0.0052	0.443	0.0075	0.469	0.0098	0.488	0.031	0.584	0.054	0.638
0.0053	0.444	0.0076	0.470	0.0099	0.489	0.032	0.587	0.055	0.640
0.0054	0.445	0.0077	0.471	0.010	0.490	0.033	0.590	0.056	0.641
0.0055	0.446	0.0078	0.472	0.011	0.496	0.034	0.592	0.057	0.642
0.0056	0.447	0.0079	0.473	0.012	0.502	0.035	0.595	0.058	0.644
0.0057	0.448	0.0080	0.474	0.013	0.509	0.036	0.597	0.059	0.646
0.0058	0.449	0.0081	0.475	0.014	0.514	0.037	0.600	0.060	0.648
0.0059	0.450	0.0082	0.476	0.015	0.520	0.038	0.602	0.061	0.650
0.0060	0.451	0.0083	0.477	0.016	0.526	0.039	0.604	0.062	0.652
0.0061	0.453	0.0084	0.477	0.017	0.531	0.040	0.606	0.063	0.653
0.0062	0.454	0.0085	0.478	0.018	0.536	0.041	0.609	0.064	0.654
0.0063	0.456	0.0086	0.479	0.019	0.541	0.042	0.612	0.065	0.656
0.0064	0.458	0.0087	0.479	0.020	0.545	0.043	0.614	0.066	0.658
0.0065	0.459	0.0088	0.480	0.021	0.549	0.044	0.616	0.067	0.659
0.0066	0.460	0.0089	0.481	0.022	0.552	0.045	0.619	0.068	0.660
0.0067	0.461	0.0090	0.482	0.023	0.556	0.046	0.621	0.069	0.661
0.0068	0.462	0.0091	0.482	0.024	0.560	0.047	0.624	0.070	0.662
0.0069	0.463	0.0092	0.483	0.025	0.563	0.048	0.626		

is also large, from the water-shed of the Genesee, with its gently rolling farm lands and few woods, to the heavily forested head-waters of the Rondout and Upper Hudson. The effect of forests on the quantity of rainfall and run-off is believed to be slight, but, on the distribution of run-off throughout the year, it is very marked. Other things being equal, a water-shed which has been denuded of its forests will have a much lower minimum discharge in summer and will be subject to more violent floods in times of high water.

Table 3 is a comparison, for various water-sheds, of the run-off computed by the formula and the recorded observed run-off.

It will be noticed that the closest agreement between the computed and the observed run-off is for the water-sheds where the data are the most reliable, for instance, the Hudson, Genesee, Esopus, and Croton. Furthermore, where there is any material variation, the computed quantities are generally less than the observed. Accordingly, the use of the formula for estimates of flow will be likely to give quantities which are less than the actual, rather than those that are more; that is, the error is on the side of safety.

The formula is also applicable for the computation of run-off for individual years. For illustration, take two water-sheds, the Hudson

and the Esopus. In the case of the Hudson, $S = 0.0149$ and $T = 41.9$. and the formula becomes, $C = 0.934 \dfrac{0.520\ R^2}{41.9}$,

$$\text{or } C = 0.0116\ R^2.$$

In the case of the Esopus, $S = 0.0468$ and $T = 44.5$, and the formula becomes $C = 0.934 \dfrac{0.623\ R^2}{44.5} = 0.0130\ R^2$.

TABLE 3.—COMPARISON BETWEEN OBSERVED RUN-OFF AND RUN-OFF COMPUTED BY THE FORMULA, $C = 0.934\ S^{0.155} \dfrac{R^2}{T}$.

Water-shed.	Mean annual rainfall observed, in inches.	Mean annual run-off observed, in inches.	Mean annual run-off computed, in inches.	Difference, in inches.
Rondout	46.7	28.5	28.5	0
Sudbury	45.7	23.6	21.3	2.3
Connecticut	43.5	23.8	21.1	2.7
Lake Cochituate	47.3	20.4	21.5	1.1
Esopus	48.3	30.1	30.4	0.3
Nashua	48.7	25.4	28.2	2.8
Tohickon	48.4	26.7	23.5	3.2
Croton	49.3	22.6	23.0	0.4
Perkiomen	47.6	23.6	22.6	1.0
Passaic	46.8	25.3	20.7	4.6
Neshaminy	47.8	22.8	20.7	2.1
Genesee	40.4	14.3	14.9	0.6
Muskingum	42.4	15.1	13.3	1.8
Hudson	44.5	23.5	22.9	0.6

TABLE 4.—COMPARISON BETWEEN OBSERVED AND COMPUTED RUN-OFF FOR VARIOUS YEARS, FOR THE UPPER HUDSON.

Year ending December 1st.	Rainfall observed, in inches.	Run-off observed, in inches.	Run-off computed by formula, in inches.	Difference, in inches.
1888	43.9	23.6	22.3	1.3
1889	43.0	21.7	21.5	0.2
1890	50.4	28.9	29.5	0.6
1891	43.0	20.6	21.5	0.9
1892	53.9	33.1	33.5	0.4
1893	42.2	21.9	20.8	1.1
1894	42.0	19.4	20.4	1.0
1895	36.7	17.5	15.6	1.9
1896	45.2	23.6	23.7	0.1
1897	46.5	26.2	25.0	1.2
1898	48.5	27.1	27.3	0.2
1899	35.8	19.5	14.9	4.6
1900	45.4	20.7	23.8	3.1
1901	42.6	21.9	21.0	0.9

TABLE 5.—Comparison Between Observed and Computed Run-off for Various Years, for the Esopus.

Year ending October 1st.	Rainfall observed, in inches.	Run-off observed, in inches.	Run off computed by formula, in inches.	Difference, in inches.
1907.........	41.3	22.4	22.2	0.2
1908.........	58.0	42.5	43.8	1.3
1909.........	48.5	30.3	30.5	0.2
1910.........	49.6	31.8	32.0	0.2
1911.........	37.0	19.3	17.8	1.5

These two illustrations serve to show the degree of accuracy that may be expected in the use of the formula when the rainfall and temperature data are fairly accurate.

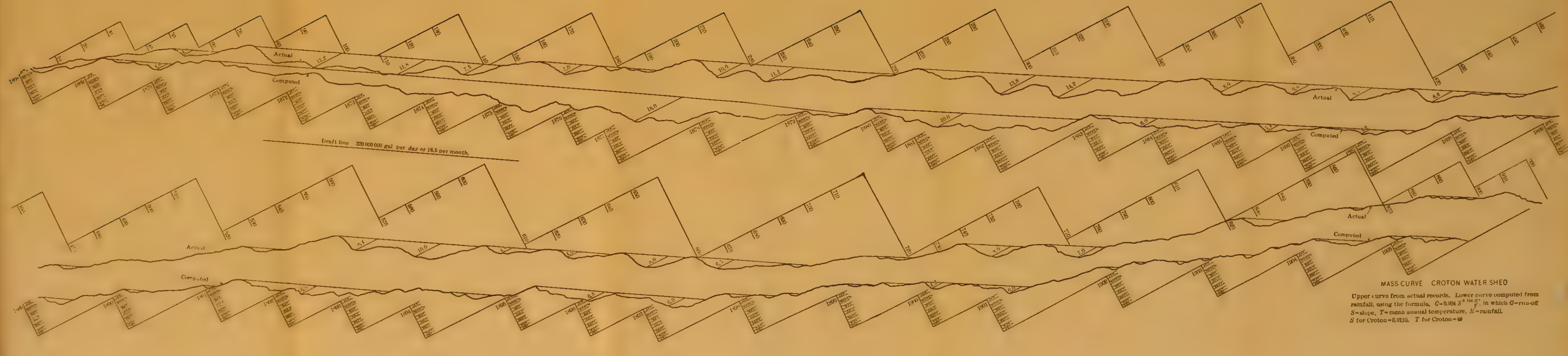
The Supplying of Missing Records.—It sometimes happens that only 2 or 3 years of good run-off records have been kept on a water-shed, and that rainfall records are available for a number of years. In such a case, the record may be extended in the following manner.

Plot on logarithmic cross-section paper points for the 2 or 3 years of known run-off, using rainfall as abscissas and run-off as ordinates. Compute the run-off for several other years, using the formula, $C = 0.934\ S^{0.155}\ \frac{R^2}{T}$. Plot the corresponding points. Then draw a straight line parallel to the line, $Y = X^2$, among these points, giving greater weight to the observed data. This line will be represented by the equation, $C = K\ R^2$. Having this curve, the run-off for any year may be read off, using the rainfall as argument.

Application to the Mass-Curve.—Engineers are frequently called on to construct reservoirs of considerable capacity on water-sheds where accurate run-off data are lacking. For the determination of the necessary capacity of a proposed reservoir, the mass-curve is the accepted method. Having given a water-shed without run-off data, but with rainfall records available, a satisfactory mass-curve may be constructed by using the formula, $C = 0.934\ S^{0.155}\ \frac{R^2}{T}$. The values of S and T are generally easy of determination for any particular water-shed.

In using this formula for the construction of a mass-curve, it is applied to the rainfall for each month consecutively, and the resulting monthly run-off is used in constructing the mass-curve in the usual manner. Of course, using the formula in this way, the resulting com-

PLATE LXXVII.
PAPERS, AM. SOC. C. E.
AUGUST, 1913.
JUSTIN ON
DERIVATION OF RUN-OFF FROM RAINFALL DATA.



MASS CURVE CROTON WATER SHED

Upper curve from actual records. Lower curve computed from rainfall, using the formula, $C = 0.934\, S^{0.155} \frac{R^2}{T}$, in which C = run-off S = slope, T = mean annual temperature, R = rainfall.
S for Croton = 0.0110. T for Croton = 49

puted run-off for individual months will often be very different from the actual; but, in the study of large water-power or water-supply projects, where water must be stored for several months, this will not affect the conclusions as to the necessary size of the reservoir for a given draft.

The most expeditious method of applying the formula for this purpose is as follows:

Compute several values of C for given monthly values of R. Plot these computed values of C, with the corresponding values of R, on logarithmic cross-section paper. The points will lie in a straight line. This logarithmic curve may then be used for picking off values of C for given values of R.

On Plate LXXVII are shown two mass-curves for the Croton water-shed. The upper curve was obtained from the recorded run-off data, and the points on the lower curve were computed by the formula, $C = 0.934\,S^{0.155}\,\dfrac{R^2}{T}$. It will be noticed that the cumulative totals of the observed run-off for 37 years differs from the computed by about 3%, the computed being less than the observed. A draft on the water-shed of 1.65 in. per month, or 320 000 000 gal. per day, was assumed and applied to the curves. The greatest depletion shown on the curve of observed run-off was 14.2 in., and the mass-curve of computed run-off showed a depletion of 18 in., a difference of 21 per cent. This difference, however, is on the safe side. It is customary to build reservoirs with a capacity of from 20 to 30% in excess of the depletion shown by the mass-curve. Had there been no run-off data in existence on the Croton water-shed, a reservoir of sufficient capacity could have been decided on from a study of the computed mass-curve.

In a similar manner, two mass-curves were plotted for the Nashua water-shed, one from the observed run-off data and the other from computed run-off data obtained by using the formula. A draft of 1.852 in. per month, or 125 000 000 gal. per day, was assumed. The greatest depletion on the curve of observed run-off was 10 in., and on the curve of computed run-off, 12 in., an error which is again on the safe side.

The mass-curves of observed run-off and of computed run-off were plotted for the Esopus water-shed. A draft of 1.825 in., or 250 000 000 gal. per day, was assumed. For the curve of observed run-off, the

greatest depletion was 8.2 in., and, for the curve of computed run-off, the greatest depletion was 7.5 in. The difference, 0.7 in., though not on the safe side, is so small that it could not affect materially the size of the reservoir decided on.

Conclusions.—The writer is not of the opinion that the gauging of streams and the accumulation of run-off data should be abandoned, and the method herein described established in their place. Accurate run-off data are scarce, and engineers need far more. These methods and formulas are applicable to water-sheds where run-off data are meager or lacking, and it is believed that they will give more reliable results than those now generally in use.

The formula, $C = 0.934\ S^{0.155}\ \frac{R^2}{T}$, is, the writer believes, applicable to the Eastern United States, and, in general, should give results within 10% of the true run-off. In applying the formula to other watersheds, the writer would advise caution. Although the formula is believed to be general, it is possible that, if more data were at hand on the relation of run-off to rainfall, the value of the constant (here 0.934) and of the exponent of S (0.155) might vary somewhat in other sections of the country, where there is a marked difference in climatic conditions.

Of course, if this formula is applied to the rainfall for some particular month it will not give the true run-off. It has been shown, however, that it may be used for obtaining monthly run-off, and that the mass-curve when plotted gives depletions which do not differ materially from those obtained when the observed monthly run-off is used in constructing it.

At first sight, the application of the formula may appear to be complicated, but, by using Table 2, which gives the values of $S^{0.155}$, it is simple; and if logarithmic plotting is utilized, as suggested, it becomes merely a matter of reading off the curve.

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THE EFFECT OF SATURATION ON THE STRENGTH OF CONCRETE.

BY J. L. VAN ORNUM, M. AM. SOC. C. E.

TO BE PRESENTED NOVEMBER 5TH, 1913.

The paucity of recorded information concerning the treatment of concrete specimens, with regard to moisture conditions during their storage while awaiting the test for strength, seems to indicate a general supposition that this feature has no considerable effect on results. Apparently corroborating this attitude is the statement in the recent report of the Special Committee on Concrete and Reinforced Concrete, in which, while specifying the exact dimensions, mixing, consistency, age, etc., of test specimens, the only requirement designed to control moisture treatment during their curing seems to be that they shall be "stored under laboratory conditions." It is the purpose of this paper to invite attention, not only to the great importance of specifying and standardizing the moisture treatment of specimens intended for testing, but also to the further fact that similar conditions, as they act on the finished structures, will affect their strength considerably, and therefore should be considered in specifying the proper unit stresses. It is evident that this factor should not be ignored when great variations in strength, to an amount of perhaps 50% above or below a mean value, result from differences in moisture conditions.

NOTE.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

During the last six years this question, at times, has been the subject of investigation in the Washington University Testing Laboratory. Different features have been explored experimentally, as work on graduation theses, since 1907 by Messrs. Trelease, Feinberg, Harris, Start, Bank, Caplan, Bryan, and Keller. Although these tests leave the greater part of the field still untouched, the writer believes the results thus far obtained to be so definite in their showing of a decided influence of moisture conditions on strength, and so significant in their general indications, that he offers this summarized statement of experimental results to the Engineering Profession for its consideration.

The most important part of the investigation is that of the effect, on the compressive strength of concrete, produced by varying systematically the relative length of time of exposure in air and in water.

The test specimens were cylindrical, 8 in. in diameter and 16 in. high. The materials were: a standard brand of Portland cement which fulfilled thoroughly all the requirements of the standard specifications; a clean sand of good quality, weighing about 110 lb. per cu. ft. when dry, and having 36% voids; and a washed river gravel of the same weight, varying in diameter from quite small up to 1½ in., and having 33% voids. The proportions were the usual 1:2:4, by volume; the mixing was done thoroughly by hand; and the quantity of water used was such as to give a moderately wet consistency, which allowed a thorough compacting by stirring with an iron rod and a slight tamping. All details of fabrication, curing, and testing were planned so as to secure such complete uniformity as is practicable to obtain in all regards except the one for which the controlled variation formed the particular purpose of the experimental study.

The cylinders were removed from the moulds when 2 days old, and were tested at an age of 6 weeks. The intervening 40 days constituted the period in which the duration of their immersion in water was varied systematically from nothing to the full time. The average results of the 240 tests thus made are plotted on the diagram, Fig. 1, on which the abscissas represent that number of days (after the 2 days in the moulds and the time of exposure to air) during which each set of specimens was placed in water before crushing them; and the ordinates give the percentage of strength which each set of immersed cylinders (standing in water for the indicated number of days) was found to have, taking the compressive strength of the dry specimens

from the same mix as 100 per cent. Thus, at the extreme left is represented the basis of comparison, or those which were not immersed at all; those specimens which were cured in air of ordinary humidity for 32 days and then immersed for 8 days are shown by the black circle to be 86% as strong as the air-cured concrete; those in air for 12 days

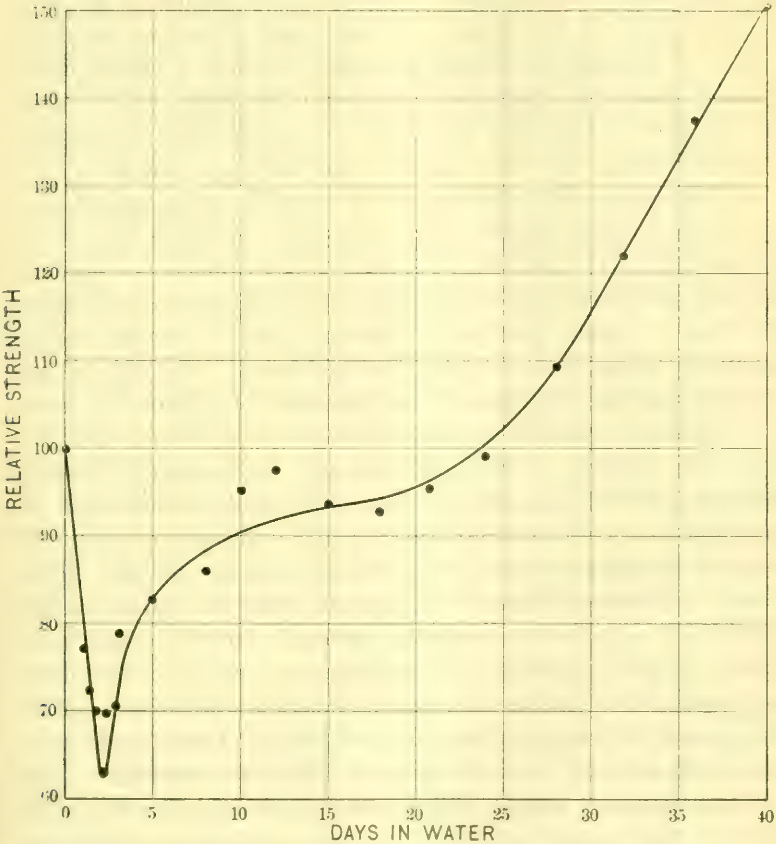

FIG. 1.

and therefore finally cured in water for 28 days have gained 9% in strength; and those submerged for the entire 40 days exhibited an average compressive strength fully 50% greater than that of the air-cured specimens.*

* Some other experiments have also shown that concrete aged entirely in water is considerably stronger than when left continuously in air, as reported by Rafter, Withey, and the Watertown Arsenal.

An average curve for the plotted points has been drawn as a full line, showing the systematic increase in strength as the time of submergence is lengthened beyond 2 days; but there exists the significant fact that specimens, of the dimensions used, decrease rapidly in strength when stored in air for 38 (or more) days and then placed in water for the remaining 2 days (or less). This particular feature of the rapid loss of strength on first exposure to water, and the active but slower recovery of strength as soaking continued, required a multiplication of tests to determine satisfactorily the locus of the curve in this region; and consequently more than half of the experiments were concentrated in this descending and the adjacent rising portion of the plot.

It thus appears that the compressive strength of concrete exposed only to air may be reduced nearly 40% when saturated with water, but that this loss is actively regained as the treatment is continued. The word saturation is used advisedly, because the minimum strength was found to coincide practically with the length of time required for water to penetrate to the middle of the specimens. Very plainly, this loss of strength has no relation to the percentage of contained moisture, as it is not only regained but much exceeded if the saturation is continued long enough. Perhaps the reduction in strength is purely a temporary physical phenomenon which is gradually counteracted and finally dominated by continued saturation permitting the imperfectly developed chemical processes of hardening to proceed actively. If this be true, concrete would regain something more than its original strength if dried out as soon as completely saturated, but this value would be less than that attainable by a continuance of the water treatment; also a repetition of soaking after such an experience would again temporarily reduce the strength, but less than before. These questions, as well as others, such as the duration of saturation necessary to prevent the temporary relapse of strength described, the corresponding effects of other periods of treatment similar to that discussed, of alternating the exposure to air and water, the result of different dimensions, proportions, materials, etc., all offer a large, interesting, and fruitful field for investigation.

In a series of experiments on the factors affecting the strength of bond between concrete and embedded steel, 74 tests were made to determine whether there existed the same tendency of rapid weakening at first and a following recovery of strength when the dry specimens

were immersed in water. The concrete was of the same character as already described, and the test specimens were partly of the notched beam type transversely loaded, and partly of cylindrical form in which the rod was pulled from the embedding concrete. All care was used to make the methods of testing such as to minimize all variables except the particular one the effect of which was sought. The results indicate clearly, for both plain and deformed bars, that the bond strength values, similarly, decline rapidly and then increase after saturation is complete, as is the case with the compressive strength; although the average minimum observed was only about 75% of that of the specimens cured entirely in air. Whether or not this percentage really marks the greatest weakening of bond produced by immersion at an age of 6 weeks is somewhat uncertain; perhaps additional tests for intermediate periods of soaking would have developed a further reduction in strength. At any rate, a similar behavior characterizes the bond values obtained during the first few days of saturation.

Thirty-two beams were made of such dimensions and amount of longitudinal reinforcement (without any web reinforcement whatever) that failure would always occur through the effect of the excessive web tension in the concrete. The materials were of the same quality as those already described, and equal precautions were taken to secure reliable results. These beams were also tested at an age of 6 weeks, but the small number restricted the investigation to lengths of immersion designed to detect only the early loss of web tensile strength and its subsequent increasing value, without tracing it throughout successively lengthening periods of exposure to water to the limit of 40 days. The characteristic effect is again the same, the lowest average found being again practically three-fourths of the strength of the air-cured specimens. It may be that, in this case also, the minimum value was not detected.

A series of experiments on concrete prisms when 7 years old, to determine any change due to age in elastic properties, has been discussed previously by the writer.* It may be stated, in reference thereto, that the modulus of elasticity of these old prisms exhibited a practically constant value throughout the repeated loadings equal to the maximum before found, which was about 80% greater than the final

* *Transactions*, Am. Soc. C. E., Vol. LVIII, pp. 312-13.

constant value as then reported for prisms of ordinary age; or a value of 4 000 000 in compression for that 1 : 3 : 5 limestone concrete. In these experiments two specimens were immersed in water until saturated and then carefully tested; the resulting compressive modulus of elasticity for wet concrete was 60% of that observed on the same specimens when dry. This lowering in value refers, again, only to the effect produced as soon as the saturation is complete; and has no reference to a continuance of the exposure to water, such as is reported on certain other tests,* where the figures given for the compressive modulus of elasticity of concrete specimens cured entirely in water for 26 days are about one-fourth greater than for those cured only in air.

As the various strength values of dry concrete are temporarily reduced from 25 to 40% by saturation, it would seem that this fact should be given definite consideration in fixing the working stresses used in the design of structures which may be thus exposed, or else conditions should be controlled in such a way as to prevent the weakening thus produced. No such effect occurs in concrete constantly under water or in moist earth from the time of its fabrication; but construction above ground, and therefore exposed to dry air for a time and then to a heavy rain or other source of rapid wetting, presents conditions under which this reduction in strength exists temporarily. Fortunately, the remedy is simple and inexpensive. It is to keep the exposed material thoroughly wet until its enclosure by exterior walls and roof renders its saturation by rain impossible. The case of parts not thus protected, or those for which enclosure is delayed, is not so simple; because the length of time of saturation which will make the concrete safe against serious reduction of strength is uncertain. The systematic wetting of concrete is a well-known principle of good construction; but the writer's observation and experience suggest a very considerable tendency to regard that procedure as abstractly correct, but practically rather specious or trivial. One purpose of this paper is to present the facts in such a way that the frequent, thorough, and faithful wetting of all parts of such concrete structures shall henceforth be no more ignored than is now the protection from freezing or disturbance while setting. Probably this treatment should be continued

* *Bulletin No. 175*, University of Wisconsin, p. 17.

for a length of time substantially greater than that heretofore indicated—perhaps for a period expressed in weeks instead of days.

Undoubtedly, carelessness in a thorough control of this kind is a frequent contributing cause of weakness which is sometimes sufficient to result in failure. Very evidently, this temporary weakening of concrete by saturation is amply covered by the factor of safety required by good practice, if it be the only fault; but the materials may be considerably below standard, or the workmanship may be defective, or the design may encroach on the reserve of safety, or the occasional overload may be imposed; and if the material man, the construction superintendent, the designer, and the user of the structure should each rely on the others to meet fully the requirements, in the expectation that his own delinquency will be safely covered by the factor of safety, it would not require an impossible coincidence of such conditions to cause disaster; especially in view of the fact that considerable variations from the average strength values, which form the basis of design, necessarily exist in different parts of the structure. In fact, the failures which have occurred are generally a result of several such contributing causes. The writer believes that the considerable weakening produced by the saturation of dry concrete has invariably been a contributing factor in all those instances in which there was an active wetting of dry or partly dry concrete when subjected to essential stresses.

This general proposition furnishes one more evidence of the remarkable responsiveness of concrete to variations in its treatment. The fact that differences in control (which to the average artisan are seemingly unimportant) actually do exert a positive influence on its essential characteristics, constitutes a definite warning against entrusting it to the uncertainties of irresponsible or skeptical supervision, and assures ample reward for a competent control which is correctly adapted to develop its capabilities. The susceptibility of steel to the influence of phosphorus and sulphur, of details of its heat treatment, and of other conditions occurring in the process of its manufacture, have resulted in restricting its production to the scrutiny of expert superintendence. Equal reason exists for, and commensurate advantages will follow, a thoroughly discriminating control of both the initial fabrication of concrete, and the details of treatment during its hardening, in order to realize the great possibilities inherent in this newer material.

The treatment of steel is not always complete as it comes from the rolls, as is shown by such effects as the changes in strength produced by the cold-twisting of steel rods; much more important in relation to the resulting quality of concrete is the nature of its treatment after fabrication, both because its attainment of strength is a relatively slow process and for the reason that the nature of the prevailing conditions provided during this period affects so greatly the development of its essential properties.

The notable responsiveness of concrete to the character of its treatment is a direct appeal for thoroughly trustworthy and expert control.

AMERICAN SOCIETY OF CIVIL ENGINEERS

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ADDRESS AT THE ANNUAL CONVENTION, IN OTTAWA, ONTARIO, JUNE 18TH, 1913.

SOME TENDENCIES AND PROBLEMS OF THE PRESENT DAY AND THE RELATION OF THE ENGINEER THERETO.

BY GEORGE FILLMORE SWAIN, PRESIDENT, AM. SOC. C. E.

In asking your attention this morning to the remarks which I shall offer for your consideration, I cannot forbear expressing to you, once again, my appreciation of the honor which you have done me in electing me to the position in which I find myself. It is a distinction which I shall always value above any other, and it involves a responsibility to the profession of which I am deeply sensible. This feeling, together with my conviction of the importance of our profession as a part of the social organism, has guided my choice of a subject for this address.

As we gather here, interested in widely divergent branches of engineering science, it has seemed to me that I could most profitably occupy the time by asking your attention to some matters in which we all should be equally interested. I have, therefore, chosen for my subject a consideration of "Some Tendencies and Problems of the Present Day," and the part which the engineer should play in their solution.

We are living in a most remarkable age, an age different from any that has preceded it in the history of the world, and one in which changes are taking place with marvelous rapidity. As a profession, we are largely responsible for the present conditions, and therefore we should

do our part in solving such problems as exist, and in helping to direct aright the tendencies of the day. We have a duty to ourselves, to our profession, to society, and to our successors, and we must perform it.

We have been often reminded of the fact that in one sense engineering is the oldest of the professions, since engineering constructions of some form are necessary even in the rudest communities; but in another, and perhaps a truer sense, it is the youngest of the professions. The priesthood is doubtless the oldest distinct profession recognized as such, for the most uncivilized tribes had priests to mediate between themselves and their crude deities. The priests were also lawgivers, practiced the healing art (such as it was), and, as civilization progressed, were also the builders. Bridges and temples were built by them, and the most stately buildings were those devoted to ecclesiastical uses. In course of time, the lawgiver, the physician, the architect, became distinct, and then for a time the engineer was either an architect or a priest. It is fair to say that engineering is the last profession to be differentiated into a class by itself, and that its beginning dates from about the Seventeenth Century, later receiving its great impetus from the series of inventions which were made toward the end of the Eighteenth Century—the spinning jenny, the loom, the puddling process, the steam engine, and the steam locomotive. Since that time, the profession has grown by leaps and bounds, has become separated into a dozen branches, and has probably become, directly or indirectly, the chief occupation of mankind. If this age may be designated as predominantly that of any profession, it is certainly the age of the engineer or applied scientist. He furnishes us with thousands of comforts, necessities, and luxuries, of which previous generations never dreamed, and which they would have laughed at as impossible. By supplying the fundamental material elements of modern civilization—transportation, the transmission and dissemination of intelligence (by telegraph, telephone, and printing press), machinery, prime movers, and the working of metals—the applied scientist becomes the minister to the other and older professions, furnishing tools for the surgeon and dentist, and chemical products for the physician; while engineering projects and problems probably supply as large a field as any for the employment of lawyers. The priest—originally lawgiver, physician, and builder—now stands alone, concerned only with the moral law and its application, and with our relation to the Infinite.

Civilization, as we know it to-day, then, seems to me to be due mainly to the engineer, or applied scientist, using the term in its widest sense. Of course, a great ethical advance has also been made, of which any student of history must be fully conscious; but, when we consider that moral principles were known and recognized by the ancients, in as perfect a form as that in which they can be stated to-day, without producing much, if any, wide-spread ethical progress, or any advance in civilization, for many centuries, we must, I think, conclude that it is the dissemination of intelligence, the facilities for transportation, the development of machinery, which have made the whole world kin, and thus have been the chief elements in promoting the universal brotherhood of man and the practical recognition of human rights, and so have been the main agents in the progress of civilization. This, somewhat differently expressed, is, as I understand it, the position taken by Buckle, often misunderstood by those who assume him to assert that no ethical progress has been made. However this may be, few will deny that the work of the engineer, if not the cause, has been a necessary condition, of progress.

This progress, both material and ethical, has been wide-spread, and astonishing in degree. In material things, not only necessities, but comforts and luxuries of which our forefathers would never have dreamed, are now within the reach of every man who is sober and industrious. Wages have risen, not only in absolute amount, but in purchasing power. The poor can now receive medical advice, medicines, and many other things free, where our predecessors could not have obtained the same things at all. Simple foods in great variety, and clothing of good quality, can be obtained at reasonable prices; and in every respect the poor man to-day is better provided for than his predecessors were. Ethically, too, he is far better off. The best books are available, if he wants them, at ridiculously low prices, free public schools are provided for his children, and all sorts of free industrial and vocational instruction is available for him in his leisure hours if he desires to use them. His hours of labor have been shortened, his civil rights have been generally recognized, he is treated as the equal of any man before the law, and his right to a fair chance in life—to opportunities commensurate with his ability to make use of them—is generally admitted in theory, if not yet entirely in fact. With free public and trade schools, with conditions which allow a common laborer

in a steel mill at 15 to become the head of the greatest industrial organization in the world at 50, certainly it cannot be said that men do not have opportunity in the United States.

Continued progress, however, and the interest of the social organism as a whole, require that individual initiative and ability shall be encouraged to the utmost and allowed to enjoy the reasonable fruits of its exercise; that property shall be protected; that taxation shall be equitable and uniform; that leaders shall be chosen from those most enlightened, capable, honest, and judicious; that those who are only fitted for manual labor shall not acquire a distaste for it or look down upon it as inferior in dignity to other occupations*; and that waste and extravagance shall be reduced to a minimum. There should be a recognition of the facts that wealth must be unequally divided, since men are unequal in ability and in character; that the prosperity of one depends on the prosperity of all;† that each man must feel secure in the enjoyment of all that he can legitimately win; that wealth, position, and luxury, do not in themselves bring happiness; and that the selfish desires of the individual must be subordinated to the interests of society as a whole if progress and not retrogression is to ensue. A state of equality of condition, as has been well remarked, would mean equality, not of wealth, but of wretchedness.

The political and social evolution in the past, up to a comparatively recent period, has not involved any diminution of the incentive to individual effort, nor to any great extent the attempt to deprive the individual of the fruits of his industry and ability. Of late years, however, with growing political power in the hands of the less intelligent classes, symptoms of a change have shown themselves. The spectacle of isolated instances of great wealth acquired unfairly or too rapidly, and of rewards out of proportion to service, instead of being looked upon as necessary phenomena, seeing that men are human, and that no human affairs can ever be perfect, has led to a wide-spread spirit of envy and discontent, and sometimes to a desire to deprive men of the results of their honest toil.

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*"But we exhort you brethren * * * that ye study to be quiet, and to do your own business, and to work with your hands," wrote the Apostle Paul.

†"This, then, above all, ought to be regarded by every one as an established principle, that the interest of each individual and that of the entire body of citizens are identical, which interest, if any one appropriate to himself alone, he does it to the sundering of all human intercourse." Cicero, "De Officiis."

It is to some unfavorable phenomena incident to this movement that I wish to call your attention to-day, believing that, if they continue, disaster may result, in which case, as always, the suffering will mainly come upon those least able to bear it.

1.—In the first place, let me refer to the tendency to consider men equal, or to what I may term a false democratic ideal.

What I conceive to be the true democratic ideal is this: that all men are equal before the law—so that neither differences in wealth, race, social position, nor talent, shall confer any advantage or impose any disadvantage in the impartial administration of justice; that while ability should be admired, every man who is honest, industrious, sober, and faithful, and who does his work in the world as well as he can and with due regard to the rights of others, is deserving of equal respect and regard, whether he occupy the humblest or the most exalted position; that success depends on the spirit with which one's natural endowments are utilized and the degree to which they are developed, and not on those endowments themselves, so that the humblest laborer on the street may be making as great a success of his life as the most gifted; that there should be kindliness and a spirit of brotherhood between all men, and neither envy of those more capable, who receive greater rewards, nor contempt of those less gifted, who do the menial work of the world; and that neither race, poverty, nor inferior social position, should prevent the possibility that a man, by hard work, integrity, and conscientiousness, should be able to reach, by some available ladder, a position commensurate with his abilities. A man should be judged by what he is, not by what he has, whether he is black or white, or who his grandmother was. He should have the opportunity to get such education as best fits his natural qualifications. Rich and poor should be judged by the same standard—inherent worth. But, though respect should be equal, rewards should not be. They should be in proportion to the value of the service, and governed by the law of supply and demand; nor are great rewards necessary for happiness.

Unfortunately, a democratic government, especially with universal suffrage, instead of tending to the realization of this ideal, tends in some respects directly away from it, and leads not seldom to the grossest perversions of it. The equality of man, which the framers of the Declaration of Independence held to be self-evident, instead of being

interpreted as above, is held to mean that men are inherently equal in all respects.

It is self-evident that, instead of being equal, men are very unequal. There is perhaps more difference between the most intelligent and the least intelligent voter than there is between the latter and an intelligent animal. It is held that all, being equal, should have equal opportunity; but why should there be equality of opportunity for unequal individuals? As Harris remarks, "Inequality of opportunity for unequal men is a nearer approach to true equality than equal opportunity for unequal men." Why, for instance, should all men have opportunity for a college education, when only a few can profit by it, and the great majority should work with their hands, not with their heads? Not every man who is able to pass successfully through a college course is able to use it when he has finished, and by its means many a good mechanic has been spoiled to make a poor and discontented clerk or lawyer.

One of the conditions of individual progress is the willingness to recognize and admire superiority, and without envy to rejoice in its success. The idea of the equality of man limits this recognition, and thus hampers individual progress, and therefore collective progress. In college, there is little in class associations to stimulate a man to excel. If he does, he is termed a "grind" and is looked down upon. If all men are equal, he has no right to exhibit any superiority to his fellows. The same is true among the so-called laboring classes. No man must do any more work, or do it any better, than another. Individual excellence and initiative are discouraged. Indeed, individual freedom is not seldom infringed upon, and a man is not allowed, at times, to work at wages satisfactory to himself, when he desires to do so—a strange result of freedom, and in reality as great an outrage as any that can be quoted from the mediæval annals of despotism. With growing discontent, many minds turn to socialism, that impracticable Utopia which, as President Butler has well said, "would wreck the world's efficiency for the purpose of redistributing the world's discontent."

The idea of the equality of man, instead of allowing the best men to govern and fitting the man to the proper vocation, leads to the placing of unfit men in power, the control of large masses of men by demagogues, the judging of men by the number of votes they can

control; and thus it leads to the withdrawal of many of the best men from active participation in public affairs, because they see how little influence they can exert without the use of money or the arts of the demagogue, and that the only reward of one who unselfishly serves the public is likely to be criticism and contumely. It also discourages loyal and faithful service, and makes difficult the maintenance of proper relations between employer and employee. Where every one is his own master, it follows that every one is his own servant.

What the ultimate result will be, cannot be foretold. The political doctrine of the equality of man is still on trial. Yet, as regards the United States, where that doctrine has its fullest expression, Lincoln long ago observed that if it fails, it will not be on account of interference from without, but it will be by suicide. It behooves us, therefore, if we can, to see to it that our institutions shall not fail by suicide.

Nevertheless, it is a somewhat striking fact that several of the most philosophical and learned historians have distrusted the ultimate success of our institutions. Froude, Macaulay, and Lecky, all express the gravest doubt of the permanence of our form of government.*

*Froude, for example, writes, "I am no believer in democracy as a form of government which can be of long continuance. It proceeds on the hypothesis that every citizen is entitled to an equal voice in the management of his country, and individuals being infinitely unequal—bad and good, wise and unwise—and having rights dependent upon fitness to make use of them, the assumption is untrue, and no institution can endure which rests upon illusions."

Macaulay, too, had great doubt of the permanence of our form of government. One of his letters to a friend in America has been often quoted, but, for convenience in this connection, it may be well to reproduce it here.

"Holly Lodge,
Kensington,
LONDON, May 23, 1857.

"DEAR SIR:

"You are surprised to learn that I have not a high opinion of Mr. Jefferson, and I am surprised at your surprise. I am certain that I never wrote a line, and that I never in Parliament, in conversation, or even in the hustings—a place where it is the fashion to court the populace—uttered a word, indicating an opinion that the supreme authority in a State ought to be intrusted to the majority of citizens told by the head; in other words, to the poorest and most ignorant part of society. I have long been convinced that institutions purely democratic must, sooner or later, destroy liberty or civilization, or both. In Europe, where the population is dense, the effect of such institutions would be almost instantaneous. What happened lately in France is an example. In 1848 a pure democracy was established there. During a short time there was reason to expect a general spoliation, a national bankruptcy, a new partition of the soil, a maximum of prices, a ruinous load of taxation laid on the rich for the purpose of supporting the poor in idleness. Such a system would, in twenty years, have made France as poor and barbarous as the France of the Carlovingians. Happily, the danger was averted; and now there is a despotism, a silent tribune, an enslaved press. Liberty is gone, but civilization has been saved. I have not the smallest doubt that, if we had a purely democratic government here, the effect would be the same. Either the poor would plunder the rich, and civilization would perish, or order and prosperity would be saved by a strong military government, and liberty would perish.

"You may think that your country enjoys an exemption from these evils; I will frankly own to you that I am of a very different opinion. Your fate I believe to be certain, though it is deferred by a physical cause. As long as you have a boundless extent of fertile and unoccupied land, your laboring population will be far more at ease than the laboring population of the old world; and while that is the case the Jeffersonian polity may continue to exist without causing any fatal

Their predictions, we hope, will prove erroneous; we must make them so, if we can. Nevertheless, the more we reflect, the more I think we shall realize that out of the false theory of the equality of man have sprung many real dangers. A spirit of unhealthy discontent has been aroused, and the people, who are sovereign, endeavor, by various kinds of legislation, to realize in fact the untruth of equality. They make the common mistake of assuming that legislation is a sovereign remedy for all ills. Not knowing how to proceed, they become the prey of every selfish demagogue who, while stirring them up to exaggerate their troubles, and professing his ability to remedy them, is simply seeking his own ends. These men know that a large part of the voters to whom they must appeal are ignorant, easily swayed by claptrap, and deceived by hypocrisy, "incapable of disentangling a difficult question, judging distant and obscure consequences, realizing conditions of thought and life widely different from their own, estimating political measures according to their true proportionate value, and weighing nicely balanced arguments in a judicial spirit." The

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calamity. But the time will come when New England will be as thickly settled as Old England. Wages will be as low, and will fluctuate as much with you as with us. You will have your Manchesters and Birminghams; and in those Manchesters and Birminghams hundreds of thousands of artisans will assuredly sometimes be out of work. Then your institutions will be fairly brought to the test. Distress everywhere makes the laborer mutinous and discontented, and inclines him to listen with eagerness to agitators who tell him that it is a monstrous iniquity that one man should have a million while another cannot get a full meal.

"In bad years there is plenty of grumbling here, and sometimes a little rioting; but it matters little, for here the sufferers are not the rulers. The supreme power is in the hands of a class, numerous indeed, but select—of an educated class—of a class which is, and knows itself to be, deeply interested in the security of property and the maintenance of order. Accordingly the malcontents are gently but firmly restrained. The bad time is got over without robbing the wealthy to relieve the indigent. The springs of national prosperity soon begin to flow again; work is plentiful, wages rise, and all is tranquility and cheerfulness. I have seen England pass, three or four times, through such critical seasons as I have described. Through such seasons the United States will have to pass in the course of the next century, if not of this. How will you pass through them? I heartily wish you good deliverance. But my reason and my wishes are at war, and I cannot help foreboding the worst. It is quite plain that your Government will never be able to restrain a distressed and discontented majority. For, with you, the majority is the government, and has the rich, who are always the minority, absolutely at its mercy. The day will come when, in the State of New York, a multitude of people, none of whom has had more than half a breakfast, or expects to have more than half a dinner, will choose a Legislature. Is it possible to doubt what sort of a Legislature will be chosen? On one side is a statesman preaching patience, respect for vested rights, strict observance of public faith; on the other is a demagogue, ranting about the tyranny of the capitalists and usurers, and asking why anybody should be permitted to drink champagne and to ride in a carriage while thousands of honest folk are in want of necessaries. Which of the two candidates is likely to be preferred by a workman who hears his children cry for bread?

"I seriously apprehend that you will, in some such season of adversity as I have described, do things that will prevent prosperity from returning; that you will act like people who should, in a season of scarcity, devour all the seed corn, and thus make the next year not one of scarcity, but of absolute famine. There will be, I fear, spoliation. The spoliation will increase the distress. The distress will produce fresh spoliation. There is nothing to stop you. Your Constitution is all sail and no anchor. As I said before, when a society has entered on its downward progress, either civilization or liberty must perish. Either some Caesar or Napoleon will seize the reins of government with a strong hand; or your republic

demagogue, therefore, appeals to class interests and class animosities, and does his utmost to foment a spirit of discontent, even though every condition justifies the opposite, gaining his reward by newspaper head-lines, notoriety, public office, or not seldom, wealth secured at the expense of the public that he deceives. The spirit of servility and sycophancy which in former times led men to grovel in the dust at the feet of kings and princes, is still with us, unchanged in form, only its object is different, and its adulation is now directed to the sovereign voter—the more ignorant, the more easy to flatter and deceive. Knowing human nature, may we not doubt the man who claims to act for the good of the people; and trust him rather who frankly admits that his actions are governed by his selfish interests, but who has learned that these can only be served by promoting the best interests of all.*

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will be as fearfully plundered and laid waste by barbarians in the twentieth century as the Roman Empire was in the fifth—with this difference, that the Huns and Vandals who ravaged the Roman Empire came from without, while your Huns and Vandals will have been engendered within your own country by your own institutions.

"Thinking thus, of course I cannot reckon Jefferson among the benefactors of mankind.

"Yours respectfully,
"THOMAS BABINGTON MACAULAY."

Lecky, one of the most thoughtful of English historians, expresses in a number of places his doubts regarding the success of democracy. For instance, he says:

"Strong arguments may be adduced both from history and from the nature of things to show that democracy may often prove the direct opposite of liberty. * * * Democracy destroys the balance of opinions, interests, and classes, on which constitutional liberty mainly depends, and its constant tendency is to impair the efficiency and authority of parliaments, which have hitherto proved the chief organs of political liberty. * * *

"A despotism which secures order, property and industry, which leaves the liberty of religion and of private life unimpaired, and which enables quiet and industrious men to pass through life untroubled and unmolested, will always appear to many very preferable to a democratic republic which is constantly menacing, disturbing or plundering them." (Lecky, "Democracy and Liberty," pp. 256-260.)

Again, he says, in another place:

"In every field of human enterprise, in all the competitions of life, by the inexorable law of Nature, superiority lies with the few and not with the many, and success can only be attained by placing the guiding and controlling power mainly in their hands. * * * Yet, surely, nothing in ancient alchemy was more irrational than the notion that increased ignorance in the elective body will be converted into increased capacity for good government in the representative body; that the best way to improve the world and secure rational progress is to place government more and more under the control of the least enlightened classes. The day will come when it will appear one of the strangest facts in the history of human folly that such a theory was regarded as liberal and progressive." (*Ibid*, p. 26. Speaking about parliamentary government, he says: "In all the instances in which this form of government has been conspicuously successful, the representative body was returned on a restricted suffrage." The great German historian, Sybel, said: "The realization of universal suffrage and its consequences has always been the beginning of the end of all parliamentarism." Professor Freeman said: "The real special weakness of pure democracy is that it almost seems to require slavery as a necessary condition of its existence." Aristotle, Goethe, and Voltaire, all disbelieved in a purely democratic form of government.)

*"The men who in former ages, would have sought by Byzantine flattery to win power through the favor of an emperor or a prince, will now be found declaiming on platforms about the iniquity of privilege, extolling the matchless wisdom and nobility of the masses, systematically trying to excite their passions or their jealousies, and to win them by bribes and flatteries to their side." Lecky, "Democracy and Liberty," p. 30.

Some of the remedies for these dangers, it seems to me, are obvious. In the first place, we should realize that the statement that all men are created equal, properly interpreted, simply means that they are equal before the law, that all men should be treated with justice, should have fair opportunities, and that each should be secured in his right to the products of his own labor, and to his own liberty, so far as his acts do not injure others. Aside from this, instead of considering men equal, we should recognize and encourage inequality, for it is easily to be seen that the progress of society depends on it. Equality of condition means pauperism or savagery; the inequality of man means the division of labor, progress, civilization.

In the second place, we should encourage the recognition and admiration of superiority.

In the third place, we should preach the gospel of content, instead of discontent. "Do violence to no man, neither exact anything wrongfully; and be content with your wages" said John the Baptist. There are two kinds of discontent: one praiseworthy; one ignoble. The former springs from a laudable ambition and a desire to perfect oneself, so far as natural endowment will permit. The other springs from envy and the desire to reap the rewards of the industry of others. The former kind of discontent is to be encouraged; every man should be given an opportunity to develop himself and to be confirmed in the possession of the prizes which he may gain; but the discontent which springs from envy, which leads men to depend on government help, instead of self-help, which sanctions forms of unjust taxation which may be nothing less than legalized robbery, should in every possible way be repressed. The attention of men, instead of being concentrated on what they want, should be directed to a realization of what they have. In contrast with the conditions which existed one or two centuries ago, even the conditions of the poorest classes at the present time are immensely improved. Yet with all the reduction of working hours that has taken place in the last 50 years, and the other improvements in condition, I doubt if there is any more real happiness and content among the poorer classes. Nor have I any doubt that the excessive talk about bettering the condition of the working classes blinds them to the opportunities for their own thrift and industry.

Unfortunately, it is a vain hope that there will ever be an absence,

or even a dearth, of demagogues to stir up this spirit of unworthy discontent, but we should do all in our power to counteract it. Much of it is due to the unwise use of wealth by those who possess it, who think that money can buy everything, and is the end and aim of existence, and who, instead of being governed by a feeling of the brotherhood of man, and the spirit of respect for true worth, even in the humblest occupations, assume an attitude of superiority, or even of insolence, toward those less fortunate than themselves.

It is also vain to hope that we can ever reach a point where there will be no poverty.* This would realize what Dr. Johnson termed the triumph of hope over experience. It would mean a radical change in human nature. As long as there are masses of men who are shiftless, lazy, incompetent, and vicious, whom nobody would willingly employ, poverty will exist. Still, every effort should be made to relieve it where it is undeserved. It will be well, however, to bear in mind that suffering is a remedy, and that unwise philanthropy may do harm instead of good. If men will learn in no other way the lessons of life, they must learn them by suffering, which is Nature's cure. Of course, it is often hard to distinguish deserved from undeserved suffering. The latter may be wisely relieved; the former generally not. Surely an all-wise Creator would not have filled the world so full of it except for some good purpose, and that purpose cannot be to afford to others the opportunity for relieving it, for much of it cannot be relieved.

2.—*The Tendency to Disregard Authority.*—Out of the tendency to look upon all men as equal, spring some other tendencies to which I will refer. One of them is to disregard authority, and to consider that one man's opinion is as good as that of any other. We see this tendency about us every day; it leads to intellectual arrogance, dogmatism, and lawlessness.

Every man has presented to him, almost daily, questions which he is not competent to decide for himself, either because he has not had the necessary time, training, or experience, or because he is incapable of judging.

*"Its causes lie chiefly in incompetence, lack of energy, bad heredity, and unhealthy surroundings, rather than in a vicious economic system, or in lack of opportunity. The relief of poverty has become so judicious that few poor persons are left to suffer from want. The prevention of poverty is to be found in good sanitation enforced by the municipality, in suitable education of individuals according to capacity, and in self-help, rather than in economic revolution or in indiscriminate equality of opportunity." Harris, "Inequality and Progress."

In these days, when literature is so superabundant, it is most important to choose our advisers wisely, to know whom to trust, to discern wisdom, to select the proper books to read, to choose the best authorities to whom we shall listen, and, when we have so chosen, to consider attentively the message they bring, and to distinguish advice that springs from self-interest from that which is disinterested. There is a great temptation to form hasty or immature judgments on slight authority; and the habit, once formed, may be difficult to eradicate.

The disregard of authority is peculiarly observable in the younger generation. It is not confined to the uneducated, but is even more observable in many whose self-esteem has been increased by a course in college. Finding that men disagree on almost every subject, and that even those in positions of authority do not hold the same opinion, it is easy to conclude that one man's opinion is as good as another's. Let us examine this matter further.

The subjects of study may be broadly divided into three classes: First, the relations of abstract ideas, that is, mathematics and logic; second, natural science; third, the so-called humanities.

With regard to subjects in the first class, no observation or experience is necessary, and there will be no differences of opinion. They are not, properly speaking, matters of opinion at all. There can be no discussion as to whether two and two make four, or as to whether the three angles of a triangle amount together to two right angles.

With regard to natural science, conclusions depend to some extent on observation, experiment, and experience. Hypotheses may be formulated, experiments made, conclusions deduced therefrom; and differing conclusions may be arrived at by different persons. In this class then, there may reasonably be divergencies of opinion. These subjects, therefore, are less definite, more hypothetical, more uncertain, than those in the first class.

Under the third class are comprised what are called mental and moral philosophy, politics, government, history, language, etc. This class of subjects is even more uncertain and less definite than the second. Experiments are less conclusive, and cannot be made under determinate conditions, as in natural science, the data are more shifting and variable, experience is of great value, and extreme differences of opinion will often occur.

The thoughtful man will recognize these differences between the

various subjects of investigation. He will form his conclusions on subjects in the first class with definiteness and certainty, and will be justified in feeling confident of their correctness. He will recognize the greater indefiniteness of subjects in the second class, and if he forms definite opinions, he will hold them in a sort of tentative manner, realizing that the next experiment or discovery, or greater experience, may show them to be incorrect. He will realize the still greater indefiniteness of subjects in the third class, and though he may well form definite opinions regarding these also, he will hold them with still greater modesty, realizing that in almost every question of this character there is much to be said on the other side, and that he may be entirely wrong. Only the man who has studied the subjects in all three of these classes will realize fully the different degrees of certainty attaching to each. Such a man will be much more modest and safe in his conclusions than one who has studied only one class of subjects. It may further be remarked that a man who has studied only the third class of subjects, will be likely to be more dogmatic and less safe than one who has studied the first or the second, or both; because, not being familiar with subjects in which a great degree of certainty, or even absolute certainty, is attainable, he may assume that such degree of certainty is attainable in the subjects of the third class; whereas, a man who has studied mathematics or science, and is accustomed to definiteness, will, when he is confronted with problems of politics, economics, government, or ethics, be at once struck with the great difference in reliability of the data, the impossibility in many cases of making crucial experiments, and the fluctuating conditions involved. For this reason, it is not uncommon that scientists, mathematicians, or engineers hold and express opinions regarding politics, economics, or ethics, with much less dogmatism than less well-informed men who have devoted their attention more strictly to these last-named subjects.*

*Sir George Cornewall Lewis, one of the deepest political thinkers of England, or of all time, lays down the following rules regarding the qualities which render a person a competent authority in matters of opinion:

"The first qualification is, that a person should have devoted much study and thought to the subject-matter if it be merely speculative; and that if it be practical, he should also have had adequate experience respecting it.

"Secondly, his mental powers must be equal to the task of comprehending the subject, and they must be of the sort fitted to it.

"Thirdly, he ought to be exempt, as far as possible, from personal interest in the matter; or, if he be not exempt, his honesty and integrity ought to be such as to afford a reasonable security against the perversion of his opinions by views of his individual advantage." "On the Influence of Authority in Matters of Opinion." London, 1849, p. 27.

Lord Brougham, in his "Political Philosophy" (Vol. 1, p. 3), says: "Mathematicians who run hardly any risk of error—naturalists who run but little more—have never been so bigoted and so uncharitable as those whose speculations are fated to be always involved in more or less of doubt; and when we come to political reasoners, we find, besides the intolerance of metaphysicians, a new source of error and of fault in the excitement which men's interests, real or supposed, lend to their passions."

Excellent books on economics have been written by mathematicians or astronomers, and it is remarkable to observe how many works on these subjects have come from men who have been senior wranglers at Cambridge.

As Lewis says:

"The qualities which render a man a trustworthy authority in matters of opinion, are much rarer than those which render a man a credible witness in matters of fact. Accordingly, the honesty which induces a man to speak the truth is more common than that which induces him to form sound opinions. There are many men who, under ordinary circumstances, would never be seduced by interest to report a fact falsely or to express an insincere opinion, whose judgment might, nevertheless, be perverted by interest."*

Lecky also expresses the same thought when he says:

"There is such a thing as an honest man with a dishonest mind. There are men who are wholly incapable of willful, deliberate untruthfulness, but who have the habit of quibbling with their convictions and by skillful casuistry, persuading themselves that what they wish is right."

Indeed, one of the first principles which we must thoroughly grasp, if we wish to judge correctly as to the authority of a writer, is that personal honesty and good intentions do not in themselves constitute any sufficient guaranty of authority. History, as well as the experience of almost every man, abounds in instances of the truth that the most honest and well-intentioned men may be the worst advisers. The French have a witty saying that "virtue is more dangerous than vice, because it is not subject to the restraints of conscience." Similar is the old saying, quoted by Cicero, that "The extreme of right is the extreme of wrong."

Two of the most important requisites for authority in matters of opinion, seem to be a spirit of conservatism, and the possession of

*Loc. cit., p. 35.

good judgment. The man who is slow to advocate a change, who adheres instinctively to old ideas and practices until there is reasonable ground for the belief that a change will be beneficial, is clearly a safer guide than he who rushes into all sorts of new schemes and is ever ready to throw aside the results of years, because perfection has not been attained. Conservatism is the brake which prevents our rushing to destruction. The possession of grasp and of good judgment is also essential. By these are meant the ability to see all the elements entering into a problem and to see them in their proper proportion. The narrow-minded man does not see all the elements in a problem; such a man lacks grasp. The unbalanced man, though he may see all the elements, exaggerates some and minimizes others; such a man has poor judgment. The advice of either is unreliable.

It is worthy of fuller inquiry what the reasons are, reduced to their elements, which cause men to differ in their opinions. Take almost any subject, except one dealing with abstract relations, and opinions may be cited which are diametrically opposite. Consider such a matter, for instance, as the relation of forests to stream flow. Here we have a scientific subject, regarding which it might be supposed that experiments or observations might be made, scientific principles applied, and opinions reached which would be agreed upon by all intelligent men conversant with the subject; and yet, on this subject, and still more so on even more speculative matters, men of equal authority or experience will be found holding diametrically opposite views. Why is it?

It seems to me that, if intelligent men differ on any subject, it must be due to one or more of the following causes:

a.—One or the other is not in possession of all the facts or principles involved;

b.—One or the other may use facts or principles which are incorrect;

c.—One or the other may reason incorrectly;

d.—One or the other may see the facts out of proportion, attributing too great importance to some and too little to others;

e.—One or the other may illustrate the natural stubbornness or imperviousness of the human mind.

It is not always clearly recognized that often facts cannot be compared directly, because they cannot be expressed except in incom-

mensurable terms. For instance, if we ask which is the greater, six feet or two meters, there will be no disagreement in the answer; but, if we ask which is the more important, 10 feet or $5, or which is more important, truthfulness or beefsteak, the reply is not entirely obvious. These are not fanciful illustrations. We are continually obliged to make comparisons between things which have to do with our physical well-being and those which have to do with our moral or spiritual well-being. They are incommensurable, yet they must be compared and an opinion formed from the comparison. In planning a railroad station, for instance, one design may require the passengers to walk a certain number of feet, while another design costs more but requires less walking. Here is a comparison which must be made between feet and dollars. In such a case, some will endeavor to express the comparison in commensurable terms. They will compute, perhaps, the value of the shoe leather that would be saved in a year if all the passengers using the station have to walk the given distance less, and compare it with the interest on the additional expenditure. Similarly, the expenditure of millions of dollars is asked for electrification, the advantage urged being the saving of a certain number of minutes each day for each passenger, and because the aggregate saving of time in a year, valued at the average annual wage of an individual, amounts to a sum greater than the interest on the cost. Such comparisons are generally made by those who find their judgment unable to deal with the subject in any other way—who cannot compare except by measuring or weighing, as they have been trained or accustomed to do. Yet such persons do not realize that the comparisons they make may be entirely deceptive. Although more rapid transit may render a journey quicker, it does not follow that the time is saved. It may be usefully employed in reading, or in conversation, or in sleep, or in meditation. An additional fifteen minutes spent in going from one's house to one's office, is not necessarily lost; it may be utilized like any other fifteen minutes in the day. Even if spent solely in meditation, it would be most beneficial, for, as Arnold Bennett says, the great defect of the age is the absence of meditation. In such arguments as that for electrification the mistake is also made of not considering whether the individuals who would make the saving claimed are the same individuals who would bear the increased cost.

Referring to the classification above, it is evident that an ability

to observe correctly, the faculty of getting at all the facts, and of knowing when all the pertinent facts have been collected, the ability to reason from those facts, the possession of conservatism, the absence of stubborn persistence in holding a previously formed opinion in the face of proof of its error, and, above all, the faculty of seeing things in proper proportion, or good judgment, are essential in forming an authoritative opinion.

How can the absence of these qualities be detected? To discuss this would lead us too far, but there are one or two points to which I wish to refer. For one thing, dogmatism, or intellectual arrogance in speculative or uncertain matters, is an almost certain indication of disqualification. The man who in such matters shows intolerance of opinion, may generally be disregarded. He who in matters of opinion is cock-sure, who terms all men who disagree with him knaves or fools, who resorts to epithets and extreme statements, who asserts that all honest men should believe as he does, or who makes similar assertions, is either willfully trying to mislead, or is unworthy of credence. This is a fault which is observable particularly in the immature, whether young or old in years.*

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*Let me quote once more from Sir George Cornewall Lewis on this subject:

"Whenever a person, having formed an opinion upon grounds which appear satisfactory to himself, asserts it confidently, and adheres to it resolutely, without showing due deference to the authority of others, he is justly exposed to the charge of *arrogance or presumption* in judging. The opinion of experienced men, having a special acquaintance with the subject, is always entitled to weight, even if it be unsupported by argument. Hence, all young persons, who attempt to judge for themselves, either are, or appear to be, arrogant; as they can scarcely fail to set at nought the opinions of persons more experienced and of greater authority than themselves. It is difficult for a young man, on account of the narrow circle of his experience, to discriminate between the cases in which he ought to judge for himself, and those in which he ought to defer to the opinions of others. He ought not to form, in youth, a habit of blind submission to authority, such as the Jesuits inculcated upon their disciples; but a spirit of docility, and respect for the opinions of their elders, undoubtedly becomes the young; and it is certain that their opinions, especially on practical questions, however formed, will in general be of very little value to others, however important it may be to themselves to cultivate a habit of independent and conscientious judgment.

"Persons who have formed habits of independent thought and examination likewise generally subject themselves to the same reproach—inasmuch as they often attach an undue weight to a chain of reasoning which they have gone through in their own minds, as compared with the opinions of persons who appear to be entitled, by their experience, to pronounce authoritatively on the subject. It is no easy matter to define the point where firmness, resolution, and proper self-reliance begin. It is difficult, again, to discriminate between teachableness, humility, and reverence for high authorities, and a tame and passive submission of the understanding.

"Universally, indeed, it may be said, that no person ought to express a confident opinion upon speculative grounds, until he has ascertained, by careful investigation, the unsoundness of the reasons for a different opinion, held by practical and experienced men. If, however, after a due examination, he differs from their conclusions, he cannot, even if he be wrong, justly be taxed with arrogance. To persist in error after proper inquiry and reflection, is not presumptuous, although it may imply *other* moral or intellectual defects. * * *

"'That man' (says Hesiod, in some celebrated verses, which acquired in antiquity almost an oracular authority,)—'that man is the most excellent, who can always think for himself. He, too, is a good man who will take sound advice from others. But he who can neither think for himself, nor will listen to the sound advice of others, is a worthless man.'" *Loc cit.*, pp. 113-117.

If, therefore, we find an author proposing changes in political or social conditions who refers to eminent men at least as honest and intelligent as himself, and more learned and experienced than he is, in terms of disrespect, we may be pardoned if we surmise that his own temper and judgment are not such as to entitle his words to be received with authority. So also, if we detect what we believe to be frequent gross errors in reasoning, or a temperamental lack of the power to see things in what is clearly their proper perspective, we may save ourselves the trouble of pursuing such an author farther, even though his sentences are adorned with flowers of rhetoric or by Biblical quotations.

3.—The Disregard for Experience.—One of the most serious tendencies of the present day, particularly in the United States, a tendency which, like the disregard of authority, seems to result from that to regard men as equal, is the disregard for experience. It is a tendency fraught with great possibilities for evil, which must be recognized by every serious thinker.

In any occupation, except those which have to do with the study of purely abstract relations, which, as above explained, may be arrived at correctly in the seclusion of the study, it is almost self-evident that experience is of great value. In any occupation having to do with pure or applied science, and particularly in those having to do with man and his relations to society—that is to say, in politics, economics and government, as well as in engineering—experience is a necessary qualification for arriving at correct judgments. A person having a power of perception of mathematical relations may become a profound mathematician at an early age; indeed, the perception of mathematical truths is essentially a subjective faculty, and may be most correct and powerful when the mind is removed from the objective state. Some mathematical prodigies have reached their greatest power when mere boys, and have lost it with increasing age and contact with the objective world. In business affairs, however, no amount of reading of books or of closet meditation can take the place of actual experience; but, if all men are equal, then the boy's opinion is as good as the man's, and experience is a mere useless drag.

It seems to be an inherent tendency of our form of government to disregard the value of experience; any man is considered good for any job; all he has to do is to get the votes, by one means or another. Men

who have made little or no study of government, and who have had no experience in it, are considered capable of judging of and administering laws, and of occupying any elective or appointive position. The butcher, the baker, the candlestick-maker, are all eligible for the state legislature, for congress, for the senate, for the mayoralty, for the presidency. This condition necessarily results in gross inefficiency and waste, not always through evil intent, but perhaps more often through stubbornness, ignorance, conceit, or the unwillingness or inability to select and take good advice. We talk much of graft, and rightly condemn it; but, as Lecky has pointed out, corrupt governments are not necessarily extravagant. Graft is injurious mainly to those who practice it. Inefficiency and inexperience are much worse for society in general; and laws which hamper industry, which harass property, or which—through unwise taxation, or extravagant state expenditures for the benefit of particular classes—plunder large portions of the community, are much more injurious to the general good than the pilfering of a few thousands of dollars a year. Sir Henry Maine remarks that the form of bribery which is most to be feared in a democracy is that of "legislating away the property of one class, and transferring it to another."*

Only in one department do we recognize experience, knowledge, and specialized training as necessary, and that department is the administration of justice. No one but a trained lawyer is considered eligible for the position of judge, and in most instances, judges are appointed and not elected, and are, therefore, not driven to seek the votes of the mob, or subject to popular whim, or the arts of the demagogue. For this reason, our Courts have been rightly deemed the safeguard of our liberties. Not until our legislators and our administrators of public affairs are chosen from men trained and experienced, and who have ascended from the bottom step by step, will efficiency, economy, and wisdom be attained in our government. Whether this time will ever be reached may well be doubted. We are much less advanced in this respect than some of the countries in Europe, where the expert is more recognized and has a higher standing, and where knowledge, and particularly experience, are valued more highly than here. If financial measures are under consideration, men experienced in finance should be sought and their advice followed. In our country, experience in finance

*"Popular Government," p. 106.

seems to be to-day looked upon as a disqualification for giving sound financial advice; and it is the same with railway and other affairs. Under such conditions, satisfactory results cannot be attained. Either, as a people, we are more dishonest, or more unwise, than the people of Europe.

In these days, when higher education is a fad, there is an increasing tendency, in my opinion very pernicious, to regard book knowledge as the equivalent of experience. We are more and more inclined to regard those as able to speak with authority, whose knowledge is derived simply from books, who perhaps have spent their lives in a professorial chair, with no actual experience in the subjects they teach or write about. We shall in time learn the fallacy and danger of this; but, in my opinion, at the present time great harm is being done by taking too seriously, in questions of politics, government, economics, finance, and business, and sometimes in engineering, the opinions of theoretical men and closet reformers, whose advice we would not think of following in the conduct of our own private affairs. Some of these men will come within the class of those who, to use the phrase of Mr. E. P. Ripley, President of the Atchison, Topeka and Santa Fé Railroad, have "zeal without knowledge, and enthusiasm without sanity."

Of course, it must not be supposed that experience is everything. In some cases, experience only confirms a man in rule-of-thumb practice, works him deeper and deeper into a rut, and destroys his power of vision. Probably all of us have seen instances of men, whose long experience in doing a particular thing in a particular way has only destroyed their power to see that there is another and a better way, and whose only reason for doing that thing in that way is that they have always done it in that way. Such men, however, would never, under any circumstances, be leaders. They are the soldiers in the ranks, whose only function should be to obey orders. It not infrequently happens, in the administration of some business affair, that a new man with a fresh mind, without experience in that line, but with a power of selecting good advisers, of grasping a new situation quickly, of seeing all the elements involved and of judging them correctly, will arrive at a truer decision than another man of less grasp and judgment, though experienced in the matter in question. This, however, is no argument against experience, but simply illustrates that experience must be combined with grasp and judgment; for the new

man, before he becomes really proficient, must either gain his experience, or must be able to select his advisers well and to rely on them. If we are obliged to choose between judgment and experience, we may well prefer judgment; but experience added to judgment is unquestionably better than judgment alone.

Not only is experience discredited to-day, but we actually find inexperience put forward as a virtue by men who should know better. One candidate for an important elective office, in an address to the electors just previous to the election, urged his qualification for the post on the ground that he had had no business experience which would prejudice his judgment in the matters which would come before him. Is not this a serious disqualification—an admission that his temperament is such that experience would prejudice him, and not teach him? Do we not want men in office experienced in the affairs they are to deal with, but fair-minded and of good judgment, whose experience, instead of warping their judgment, aids and matures it? Woe be to us as a nation when we place inexperienced men in office because experience would warp their judgment.

It is, nevertheless, true that men differ greatly in the amount of experience which they need in order to perfect their powers. This will depend on the rapidity with which they can assimilate it, and the philosophical character of their minds. It has been said that the wisest man is he who can do with the least experience; that is to say, the one who does not need to have an experience repeated again and again before he learns the lesson which it teaches, but who only needs one experience to learn its lesson, and who can extend that lesson to cover other possible experiences, thus rendering the latter unnecessary.

When we are asked, therefore, to believe and advocate any proposed policies, let us train ourselves to apply certain touchstones before we commit ourselves. If the subject is one within our experience, knowledge, and reasoning powers, let us endeavor earnestly to think the matter out for ourselves and arrive at our own conclusions. In the many cases in which we cannot do this let us carefully scrutinize the policies and their proposers, to determine how much credence we can give. Let us observe whether the author asserts them dogmatically or modestly; let us note whether he makes assertions without proof, and by incessant repetition endeavors to make us believe that assertion constitutes demonstration; let us ask whether he speaks from

experience or simply from book knowledge; let us remember that he is not free from the frailties of human nature, and let us, therefore, inquire whether he has any personal interest at stake; let us assume an attitude of doubt and distrust toward all human opinions until that doubt and distrust are effectually removed. It is said that it is better to be deceived than to distrust; but, after we have been deceived, we shall be more inclined to reverse this saying, and to consider that, in the reversed form, it will be, upon the whole, safer and more conducive to our happiness. Let us be on our guard against assuming that good intentions are a guarantee of authority, and when we find ourselves in danger of being influenced by flowers of rhetoric, let us remember that "no man is more dangerous in a state than he who possesses in an eminent degree the power of moving, dazzling, and fascinating his contemporaries, while in soundness of judgment he ranks considerably below the average of educated men"; and let us further bear in mind that "an excessive love and admiration of rhetoric is one of the diseases to which democratic communities are most liable."

4.—The Tendency to Relax Discipline.—Another of the demoralizing tendencies of the equality of man is that which has led in recent years, it seems to me, to the gradual but steady relaxation of discipline. It will probably be denied by few that for the proper training and full development of the human being, discipline is necessary. Life itself is little more than discipline; it is not for pleasure; it is for work, accomplishment, development; without discipline there will be no proper development. He who is born with a golden spoon in his mouth and whose life is a continual round of pleasure, is likely to go out of the world less developed than when he entered it. "The beginning of wisdom," says Solomon, "is the desire of discipline." Work, which is itself an end, and rather to be sought than what it brings, consists largely in doing things which in themselves are uninteresting and perhaps distasteful, and we must accustom and train ourselves to be able to do this kind of work cheerfully and well. This ability will be attained only through discipline. Moreover, the man who attains a position of responsibility must be able to direct and command the work of others, and no one can command wisely until he has first learned how to obey. For this, too, discipline is necessary. Yet the tendency of recent years seems to me to have been toward a steady

relaxation of the discipline imposed by law and custom upon the growing individual.

A tendency to relax discipline is strikingly shown where its necessity is obvious, namely, in our educational system. Formerly, the boy was put through a rigid course of prescribed study, some of it interesting and some uninteresting to him; but all of it, presumably, if the course was properly prepared by a capable faculty, necessary for the end in view. The modern tendency has been to substitute what he chooses to do or likes to do. The result has been, and is, that many young men come out of our colleges with minds and faculties practically wild and undisciplined, without willingness to do as they are told; and without the faculty of concentrating their attention on unpleasant but necessary tasks; but, if all men are equal, why should the teacher have the power to impose unpleasant tasks upon the pupil?

That the tendency in education has been to relax discipline, will not, I think, be questioned by many educators who themselves appreciate what discipline is. I understand, for instance, that the National Educational Association has recently said that high schools should be allowed to omit the study of algebra and geometry, and that the colleges should be compelled to accept for admission an equivalent amount of "science." As if we could study science intelligently without a knowledge of elementary mathematics! President Hadley, in a recent address,* comments upon this and emphasizes the fact that real training in science depends upon the method, not the subject; and he adds that "fifty years ago the one course in the academic department of Yale College where modern science was really taught, was the course in freshman Greek," because it was taught by the scientific method. Would that we had more teachers like the Hadleys, father and son. Our teachers are generally, I think, chosen upon an incorrect principle; they are appointed by reason of what they know; it seems to me they should be selected for what they are—for their ability to teach, and their power of enforcing scientific discipline. We may well ponder to-day the words of that fine old English schoolmaster, Richard Mulcaster, who died 302 years ago, and who wrote:

"I would rather hazard the reproach of being a severe master in making a boy learn what may afterwards be of service to him, even though he be negligent and unwilling at the time, than that he should

*Science, May, 1913.

lack any advantage when he is older, because I failed to make him learn, owing to my vain desire to be considered a courteous teacher."

The tendency toward a relaxation of discipline shows itself also in our laws. We congratulate ourselves on our humanity, because the long list of severe penalties, which formerly existed, has been replaced by a code much less severe; but have we not gone to the other extreme, encouraging a spirit of lawlessness and an unwillingness to submit to proper restraint? If one person shoots another with intent to kill, is the crime any less when the wound is slight than when it is fatal? Why is an attempt to wreck a railroad train, or to dynamite or set fire to a building which may involve the sacrifice of many lives, any less serious than to kill a man in a quarrel? Why should not the depraved individuals who commit acts like these be at once put out of the way for the good of society. Our nerveless laws and the misdirected efforts of inflamed philanthropy condone offenses all along the line. We coddle and sympathize and send flowers, where we should be stern and insist that the good of society is the first thing to be considered. Even in our daily dealings with individuals in matters not within the province of the law, we fail to realize that a prescription often needed, instead of coddling, kind words, sympathy, and self-sacrifice, is the prompt and energetic application of the toe of the boot to the lower end of the spinal column, repeated if necessary, until relief is obtained. We are victims to-day, it seems to me, of an exaggerated humanity, as well as of a decay of discipline. Large numbers of men and women with warm hearts and good intentions are exalting sentiment above sanity, sympathy above truth, and ease above discipline.

5.—Another of the tendencies very marked at the present time, is the spirit of innovation, which seems to pervade all things; whatever is, is wrong; the social custom must be changed in order to keep up with the time. This spirit is particularly observable among the young and the immature, especially if it has been preceded or accompanied by a lack of discipline in early training. It is an instance of what Ferrero terms "that youthful spirit of innovation which is in all ages the main source both of perversion and of progress." Many of our young men, "all aflame with an enthusiasm unquenched as yet by any continuous contact with affairs," set out to reform the world, not so much because it needs reform, as because they wish to justify their

existence. This spirit of innovation is at all times one to be expected and reckoned with. Every generation, as it comes along, will endeavor to change the condition in which it finds itself, and will designate that change with the name of progress, even though it be perversion. Oh! Progress! what crimes are committed in thy name! Even if a social condition were perfect and ideal, a new generation would endeavor to change it. Youth desires change; often because it knows no better. Age becomes conservative because it knows by experience the dangers of hasty or unwise change. The spirit of equality accelerates this tendency.

The United States is often spoken of as the country of the young man; the old are laid on the shelf just as soon as they become conservative, because wisdom, experience, and the authority of age are not respected. The adage, "old age for counsel, youth for action," is modified by the omission of the first half. Old age is not regarded at all, as soon as it desires stability and permanence rather than change. This tendency is certainly much more observable in this country than in Europe, where the wisdom which comes from age and experience is recognized and utilized. Gladstone and Voltaire did their best work after they were 60; Bismarck did his after he was 50. Gray hairs are common in the highest councils abroad. Here they are considered rather a symptom of decay.

This spirit of innovation which pervades all things seems to be largely a result of scientific progress; the rapid advances made in inventions of all kinds, the improvements in the arts and manufactures, have resulted in a complete revolution of the methods in many branches of industry within a comparatively few years. Men now living were born before there were any railroads, and almost all of us can remember the time when the applications of electricity were just beginning. An industrial plant but a few years old may be out of date and unable to compete with newer and more economical installations. In engineering matters we are accustomed to see things completely remodeled within a short time.

This familiarity with industrial change and the recognition of its benefits have naturally led to the idea that everything must be reconstructed, or it is old-fashioned and out of date, even though it be a thing in which there have been no new discoveries, warranting any change whatever: music, painting, dancing, education—everything, in

fact—must be completely reorganized. This willingness and desire for change afford the opportunity for unsuccessful mediocrity and for ambitious and unscrupulous failure to foist upon the public, which eagerly accepts it, forms of change which discerning men must characterize as gross, ridiculous, and demoralizing. The result, in many cases, is a deterioration pitiable to behold. Let any one compare, for instance, the modern painting, dancing, and music, with that in vogue fifty or one hundred years ago, and he will find abundant proof of this. In politics and government, too, the same tendency, the same recklessness, the same demoralization, are equally observable.

Now, of course, an existing condition is not necessarily the best because it is old; neither is a proposed change advisable because it is new. In many cases, however, suggested changes, ignorantly proposed by those unacquainted with history, have been tried and have been found wanting centuries ago. History repeats itself. Nations, like individuals, will only learn by costly experience. Away with the old, make way for the new! We will not profit by the lessons of our forefathers, we must experiment and learn for ourselves. Is it not much better that we should try to cultivate the breadth of view, the tolerance of opinion, which will lead us neither to adhere to that which is old, from extreme conservatism, nor to indulge in rash experiments; but to study history, cultivate a sound and deliberate judgment, and endeavor to guide the inevitable spirit of innovation into proper channels; and to remember, as Lecky well says, that "an appetite for organic change is one of the worst diseases that can affect a nation?"

6.—Advancing civilization and increase of wealth inevitably lead to increased luxury and extravagance; and, with our advancing civilization, this tendency is not wanting. If the experience of the past is of any value, however, it is a serious symptom of degeneration. The sudden accession of great wealth, particularly to those who are incompetent to use it wisely, engenders luxury and ostentation, and a contempt for those less fortunate; thus stimulating, to a certain extent, an attempt of the latter, particularly if endowed with the ballot, to recoup themselves and gain what they conceive to be their rights at the expense of wealth, by various forms of unjust taxation and other well-known expedients. If it is our duty to preach the gospel of content and the inequality of man, it is equally our duty to preach the proper use of wealth, and the proper attitude of the wealthy toward

those less fortunate; and while believing that individual initiative should be stimulated to the utmost, and allowed to enjoy the fruits of its success, it may, nevertheless, fairly be questioned whether some of the rewards under present conditions are not too large, and whether men would not exert themselves as well for the prospect of a more reasonable recompense as for the prospect of unreasonable and excessive riches. But, again history repeats itself, and things move in cycles. Peace causes prosperity, prosperity gives rise to wealth, wealth gives rise to luxury and extravagance, luxury and extravagance are the source of contention, contention results in war or social revolution, these result in poverty, poverty results in peace, and so the cycle is completed.*

Ferrero, writing of the condition of Rome in the Second Century, B. C., wrote:

"The destruction of Carthage and Corinth had already worked serious havoc in Roman life, spreading luxury and ostentation among the upper classes, a distaste for work among the lower, and wastefulness and intemperance in all ranks of society."

Do we not see before us to-day in America the same phenomena? It is not the destruction of Carthage and Corinth which have worked and are working serious havoc in our life, but it is the conquest of the virgin resources of a great continent. Wealth, luxury, and ostentation are the result, and nothing is more plain than the fact that a distaste for work exists and is spreading broadly among the lower classes, and wastefulness and intemperance everywhere.

7.—The last tendency to which I will call attention is what seems to me the distinct tendency, under present conditions, and, in fact, under conditions which have existed in increasing degree as civilization has advanced, toward the deterioration of the race. The law of evo-

*The following verse is taken from a collection of old French proverbs:

"Paix engendre prospérité,
De prospérité vient richesse,
De richesse orgueil et volupté,
D'orgueil contention sans cesse,
Contention la guerre addresse
La guerre engendre pauvreté,
Pauvreté humilité,
D'humilité revient la paix,
Aussi retournent les humans."

"The following passage from Ramsay's 'Voyages de Cyrus' contains a similar view with respect to the succession of causes and effects in the affairs of nations:—'Pendant l'espace de trois cens ans la valeur des rois de Médie avoit augmenté leure conquêtes. Les conquêtes avoient engendre de luxe, et le luxe est toujours l'avant-coureur de la chûte des empires. Valeur, conquêtes, luxe, anarchie, voila le cercle fatal, et les différens periodes de la vie politique de presque tous les états.'"

lution in all species of animals and plants, the law which we ourselves recognize and follow in breeding and cultivating them, is for the survival of the fittest, the gradual elimination of the weak and unfit. This is distinctly the law of progress. In the case of man, however, there is added an element which does not exist with the lower animals or with plants, namely, the element of human reason. Under the domination of this element, has not the tendency steadily been, with the growth of altruistic ideas and the prevalence of philanthropic institutions, toward the survival of the unfit? Are we not encouraging in many ways the survival of the weak, the inefficient, the incompetent, the depraved? If all men are equal, he who is born with an inheritance which makes him depraved or incompetent is not responsible for that inheritance, and is as much deserving of preservation as the strongest and the best.

Galton, in his researches on heredity, comes to the conclusion that the average Greek of the Athenian Age was as much superior intellectually to the average European of to-day, as the latter is superior to the average African savage. At the present time, in all probability, the uncivilized races are governed by the law of evolution, the survival of the fittest; while, in the case of the so-called civilized races, the reverse seems true. The two tendencies must meet and cross at some point in the future, if they continue.

This problem is one of the most serious that confronts us to-day. I have no time, even had I the knowledge, to discuss it in detail; I will content myself with merely mentioning it. It may seem wrong to believe that all have not equal right to survive, yet it seems to me that the interests of society as a whole must lead us to the conclusion that serious evil, and perhaps ultimate ruin, await us unless some means can be devised for solving this problem and in some manner regulating the perpetuation of our species. If present-day humanitarianism leads to race degeneration, it cannot be the way of progress intended by an all-wise Creator, and we should try to see in what way we are misapplying it. The subject is manifestly beset with great difficulties. In the first place, we must define the "fit." Clearly, the term is not synonymous with the physically strong, or the wealthy; many of these are most unfit. Equally clear is it that the fit do not include those afflicted with serious hereditary disease, the dishonest, the vicious, the intemperate, the indolent, the good-for-nothing. "If any will not work,

neither let him eat," says the Apostle. Those that will not work should starve, in other words. He adds: "For we hear of some that walk among you disorderly, that work not at all, but are busybodies." May it not be that the true main-spring of progress and prosperity is an enlightened selfishness—a selfishness which leads the individual to seek as his paramount object his own good, subject only to one limitation, that no injury should be done to any one else—that not self-sacrifice, but only a scrupulous regard for the rights of others, is the condition of race progress?

And now you may very likely have asked, what has all this to do with engineering, or with the engineering profession; what is the appropriateness of a discussion of social conditions before a society of engineers? My answer is that the engineer is primarily a member of the social body; that its problems are his problems; and that he cannot avoid the responsibility of taking a share in their solution. The problem of the Twentieth Century, it seems to me, will be pre-eminently a social problem, and upon its solution will depend the happiness of mankind for years to come. Moreover, this social problem is largely, as I have shown, the outcome of the work of the engineer who, as the advance agent of civilization, has been the main factor in creating the conditions which give birth to this problem. It will be evident, therefore, that I differ from one of my predecessors who, in his annual address, intimated that social problems were out of the province of the engineer and that he should not meddle with them. On the other hand, I maintain that it is his duty to exert himself in their solution. Moreover, I consider this duty the more necessary because I believe the engineer to be well fitted—possibly better fitted than any one else—to solve these problems wisely. Let me briefly give you my reasons for this opinion.

The engineer is by training a scientific man. If his education is what I conceive it should be, and what it will be more and more in the future, it will consist of a training in mathematics, logic, science, and in the technical branches of his profession, together with a sufficient amount of study of the humanities—history, economics, language, literature—to give him a clear view of the relations of things. He will be pre-eminently by training a scientific man, but with a power of understanding and grasping social questions. Now, a scientific training has this great virtue, that its end and aim is constantly

the discovery of the truth. The truth for its own sake, independent of everything else, is the object of the scientific man and therefore of the engineer. In this respect, it is, in my opinion, the noblest as well as the most widely useful of the professions. The lawyer is not always concerned in arriving at the truth; he is too frequently tempted to make the worse appear the better reason. As one of that profession has expressed it, his object is not to get at the truth but to win cases. He is constantly under the temptation to pervert the truth, or to suppress it, if the exigencies of his case demand.

Furthermore, the engineer is exposed to a very direct personal responsibility which cannot but steady his character and increase his self-reliance and self-control. Though he does not always receive the credit of his successes, he cannot succeed in throwing the responsibility for his failures upon others. If a lawyer loses his case, as Mr. Choate once remarked, it is never his fault; he can always charge it to the prejudice of the judge, or the ignorance of the jury, or the untruthfulness of witnesses. He goes on and obtains new clients and new fame. If the doctor loses his patient, it is never his fault; he can always charge it to the disobedience or delay of the patient, or maintain that a cure was impossible. But if an engineer builds a structure which fails or a machine which will not work, the responsibility is his and he is held accountable.

Again, the engineer is a business man, for engineering is business and business is engineering; he deals with men, he has to do with financial affairs, he learns the characteristics of human nature, and his training, therefore, tends to teach him tact, moderation, conservatism, and the value of experience.

Of course, any sweeping eulogy or disparagement of any class of men cannot be truthfully made. Engineers will differ on questions of opinion, as other men will. There are dishonest, untruthful, unreliable engineers, as there are men of this type in every class. No doubt the ranks of our Society include men who will widely disagree on the questions which I have discussed; men who will hold extreme views in one direction or in the other; men who will be dogmatic, intemperate in language and in thought, inaccurate in reasoning, insincere in opinion. No class of men has a monopoly of virtue or of error. Neither are these excesses confined to men of weak minds or deficient training. As Lecky says:

"Strange veins of insanity and capacities for enthusiastic folly sometimes flaw the strongest brains, and the impetuous ebullitions of youth which impel some men into extravagances of vice, develop in other natures into not less wild extravagances of thought."

Nevertheless, on the whole, if there is anything in training and experience, may we not believe that engineers, as a class, have the training, temper, and experience which will best enable men to judge sanely and solve wisely the social problems which confront us?

What, then, may the engineer do to aid in the solution of the social problems of the Twentieth Century?

In the first place, he should consider it his duty not to retire into the technical recesses of his professional work and content himself with being the servant of other men, but should actively exert himself and take the initiative in the great problems of the day. He will find that many of these problems in their details are largely of an engineering character.

What, for instance, is involved in the problem of administering the affairs of a great city? Do they not involve, in the main, the preservation of the health, safety, property, and order of the community? and are they not, therefore, predominantly of an engineering character? Financial and legal questions of great importance, of course, are included, but why should the engineering problems be considered secondary to these? Engineers can employ financiers and lawyers, as well as be employed by the latter. I see no reason why the position of mayor of a city could not be filled at least as satisfactorily by an engineer with proper breadth of view, training, and experience, as by a man of any other profession. Yet I doubt if the mayor of any large city in the United States is or has been an engineer.

The same holds true of other administrative positions. The management of our great corporations involves problems largely of an engineering nature, and high administrative positions in these concerns are being more and more given to engineers. Even such a position as that of president of a republic is not one which the engineer should necessarily consider himself excluded from. Why is he not as well qualified to fill it as a soldier, a lawyer, or a college professor, provided his training and experience, judgment and breadth of view warrant? Two of our greatest presidents, Washington and Lincoln, though not engineers, did have some little practice in what was then

termed engineering, and one president of the French Republic has been a professional government engineer.

There is perhaps a tendency to-day toward better recognizing the qualifications of the engineer in the administration of municipalities and larger political units. The position of commissioner of public works in a city is perhaps the most important municipal position next to that of mayor. Formerly, this position was monopolized in most cities by men who were mere politicians. Nowadays, it is quite common to appoint engineers to such posts. In Boston, Philadelphia, Cincinnati, and very likely other cities, these positions are now held by trained and educated engineers, and this recognition I consider significant and deserved. Engineers, however, will not and should not be recognized in this way unless they are as individuals equal to the responsibilities involved, unless they show their interest in public questions, unless they inform themselves about them, unless they study the economic and social, as well as the engineering problems involved, and unless they assert themselves before the public. This I trust they will do more and more as years go by.

> "The fault, dear Brutus, is not in our stars,
> But in ourselves, that we are underlings."

A question which is much before us at the present day is that of conservation. Conservation, as I understand it, consists in a wise economy and proper use of the materials and resources that are afforded us by Nature. It is essentially the avoidance of waste; it does not mean that natural resources shall be withdrawn from use, but that they shall be used wisely and economically. It does not mean that the present generation shall *suffer* for the benefit of future generations, but that the present generation shall not *rob* future generations. Now, the technical problem of the avoidance of waste and the proper use of natural resources is a problem already solved. Applied scientists can tell just what to do and how to do it. They know how to utilize the power of falling water and how to transmit it; they know how to utilize coal most economically, they know how to utilize forest products without waste, how to prevent the erosion of the soil, how to conserve health. The unsolved problem of conservation—the problem which now concerns us most—is not an engineering problem, but a social one. It is to alter the public state of mind, to make people thrifty and economical instead of extravagant and wasteful. It is

thus an attitute of mind that we have to deal with. If the attitude of mind of the public toward this problem could be made the correct one, if the individual man could be made thrifty, frugal, careful, thoughtful of the future, the problem of conservation would be solved. Why should not applied scientists, who know how to solve the problem technically, lead in educating the people to perceive the necessity for its solution? Should not mere self-interest, not to speak of public spirit, prompt us to do this?

In education, too, where, as I view it, the tendencies I have referred to are plainly evident, we may as a profession exert a good influence. I have often expressed the opinion that an engineering education is the best possible education for any vocation, because it combines, or should combine, in the best proportions, the study of abstract relations with that of natural science and of the humanities. These, combined with training and experience in the profession itself, should make the engineer as well educated as any class of men. He should be sane and sensible, not likely to be carried away by fallacious economic theories; conservative, and yet safely progressive. Engineers, I think, should exert more influence than they do in education, by actively interesting themselves in it, serving on school committees, and insisting on the maintenance of rigorous discipline and the scientific method. Above all, they should aid in maintaining the standard of engineering education, and prevent it from succumbing to the prevailing tendency to relaxation of discipline. The best students do not really seek such relaxation; and schools which make students work hard and which insist on a high standard of accomplishment, will attract strong men. The tendency of the times shows this, and proves that one movement to-day is toward utilitarian and vocational training. Some of the tendencies I have referred to may be in large measure only surface currents, and a strong undercurrent may perhaps be generated in another direction if the proper means are used. This is indicated by the growth of the engineering departments of our State universities within the last thirty years, and by the surprising development of such a school as the Massachusetts Institute of Technology from its first small beginnings to its position of recognized leadership in less than one-third of a century. Let us make the engineering schools the place of refuge for those who are opposed to the relaxation of discipline which prevails so largely elsewhere.

Finally, let us inquire what this Society, representing the Engineering Profession, may do in the directions which have been suggested. We have been criticized in the past as being inactive, as taking no part as a Society in large public questions. I must frankly confess that the criticism has seemed to me in some measure deserved. Our Society is large, rich, influential, but we have been too content to sit down in dignified ease, taking little or no initiative, and allowing other and younger societies to outstrip us in actual work performed and in real influence exercised. We have had some committees which have done good work in unifying practice in relation to technical matters. In these respects, however, we have been far surpassed by two or three of the newer societies, whose committees, after long and conscientious labor, have exercised far greater influence that we have in the solution of even professional problems. It is true that this is largely due to the fact that those societies are more specialized than ours, that they are composed of men all engaged in one line of work, who could co-operate and lay down the results of experiment, experience, and opinion more easily than we could. This Society, however, is the American Society of Civil Engineers, and includes engineers in all branches and from all sections of the country. There is no reason why the engineers in the different branches should not associate themselves together in sections, or why we could not do more committee work along the various engineering lines than we have done in the past.

I believe, therefore, that we should favor the establishment of branches of the Society in various parts of the country, and of student branches in the several technical schools; and that we should urge our committees to activity, supply them with funds, and perhaps pay the mileage of members who attend meetings. The Society is rich, and it is not a philanthropic institution. If members give their time to committee work, I see no reason why they should be expected to give money, and the expense of attending many meetings may not seldom be considerable.

Moreover, we have been very loath to take any steps in formulating answers to questions which are largely matters of opinion; and we have done, thus far, little or nothing to influence public opinion in regard to questions of the day. I believe that we could and should go much farther in these directions; that we should step forward, take

the initiative, and become a moving force in the community. Let me make some more definite suggestions.

In the first place, I believe we should have a standing Committee on Public Relations, its province being to keep track of all public affairs involving engineering questions directly or indirectly, in all the States in the Union, and to take such action as may be deemed desirable to insure a wise treatment of such questions. This committee might perhaps consist of the President and Secretary of the Society *ex officio*, of a certain number of members of the Board of Direction to be appointed each year by the President, and of a certain number of members of the Society not members of the Board of Direction, to be nominated by the Board of Direction. These outside members might be in considerable number, perhaps one or more from each State, or group of States, so that the committee could keep in touch with public affairs affecting the profession in all parts of the Union.

Further, our Committee on Engineering Education should, in my opinion, be enlarged, supplied with funds, and encouraged to active and exhaustive work. If we could lay down the principles which we believe should govern in engineering education, the general curriculum which should be adopted, the proportion of the humanities which should be included, and similar matters, we might, I believe, do much good, and, while still leaving ample room for individual initiative and divergencies in practice in different institutions, render effective aid to those teachers who are striving to resist some prevailing tendencies.

In the next place, I believe it will be wise to have more committees of the Society, dealing with specific problems, than we have had in the past. You have before you at this meeting, I am glad to state, a report from the Board of Direction stating that, as provided in the Constitution, it has voted to appoint two Special Committees, to deal respectively with the Regulation of Streams and with Uniform Water Legislation. I believe that still other committees could be appointed to advantage. We have no reason to be afraid of having too many committees. We should, rather, be sure that we lose no opportunity to exercise legitimate influence on public opinion or to aid in the solution of large problems. We might well, I believe, have a standing committee on conservation, perhaps another on corporation legislation, another on the history of American engineering. Let us give our earnest attention to this matter, and let us not hesitate to

suggest any and every means that may occur to us to promote the welfare of the Society, of the profession, and of the public. The Board of Direction will be always ready, I am sure, to act promptly with any members of the Society who can show a proper field for legitimate action.

Reviewing then, the points which I have brought to your attention, I have endeavored to show that the problem of the times is pre-eminently a social problem. I have outlined some of the tendencies of the day, as they appear to me. I have given the reasons for my belief that it is the duty of engineers to aid in the solution of these problems, and that by training and experience they are well qualified to do so. If my tone has appeared to indicate a pessimistic attitude toward the tendencies of the day, I fear I must plead guilty in some degree to the imputation; whether wisely or not, as the years have gone by, I have grown more conservative, and I find myself having little sympathy with many of the tendencies which I seem to see about me. I believe that this age will be looked upon by future generations, not as an age of progress, except in some material things, but more distinctively as an age of deterioration, an age of fads, frivolities, fancies, and follies; of much reading and little thought; an age of impulse rather than an age of reason. I am not alone, however, in a feeling of dissatisfaction. M. P. Leroy-Beaulieu, writing in 1890, and referring to conditions in France, expressed himself as follows:

"Every age is characterized by its particular craze. The present craze is for education, unlimited and injudicious, and for philanthropy equally unlimited and injudicious, both absolutely superficial. By their aid we have succeeded in producing a mental condition and in creating certain social circumstances which are most unfavourable to the growth of the population."

However, after all, it is only an epoch in the history of man. It will pass away, and others will solve the problems that we leave to them. Progress is not always continuous; there are waves, reactions, times of apparent retrogression. May we only do our part, as members of one of the greatest professions, to help direct the tendencies of our day in such manner that our successors may look back upon us with approval and not with blame, and that we may aid to the utmost in forwarding the true progress of mankind.

AMERICAN SOCIETY OF CIVIL ENGINEERS

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WATER-WORKS

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THE DEFICIT THEORY OF DEVELOPMENT EXPENSE OF PUBLIC SERVICE CORporations, and an Erroneous Application of the Theory by the Wisconsin Railroad Commission. (Editorial.) *Engineering and Contracting,* v. 35, p. 671 (June 14, 1911). (Editorial indicates alleged mistakes in the application of the deficit theory; one page.)

DEPRECIATION. (Editorial.) *Engineering,* v. 83, p. 585 (May 3, 1907). (Review of recent papers on this subject; refers especially to the papers of Robert Hammond, P. D. Leake, and Lawrence R. Dicksee.)

DEPRECIATION. (Editorials.) *Municipal Journal* (London), v. 12, pp. 818, 859, 939, 999, 1059 (Sept. 11, 25, Oct. 23, Nov. 13, Dec. 4, 1903).

——*Public Service,* v. 6, p. 122 (April, 1909).

——*Stone and Webster Public Service Journal,* v. 1, p. 16 (July, 1907). (Four pages.)

DEPRECIATION; by A. Winder. *Cassier's Magazine,* v. 35, p. 539 (Feb., 1909). (States that depreciation is made up of two elements, obsolescence and deterioration; two pages.)

DEPRECIATION; by C. N. Duffy. *Progressive Age,* v. 27, p. 686 (Sept. 1, 1909). (Paper read before the Western Gas Association.)

GENERAL—(*Continued*).

DEPRECIATION; by Edwin S. Mack. *American Gas Light Journal*, v. 88, p. 971 (June 8, 1908). (Paper read before the Wisconsin Gas Association.)

——*Progressive Age*, v. 26, p. 372 (June 15, 1908).

——*Public Service*, v. 7, p. 42 (Aug., 1909).

——Editorial. *Progressive Age*, v. 26, p. 362 (June 15, 1908).

DEPRECIATION; by Frederick Walmsley. *Municipal Journal* (London), v. 12, p. 932 (Oct. 23, 1903). (Abstract of paper read before the Society of Incorporated Accountants.)

——Editorial. *Municipal Journal* (London), v. 12, p. 939 (Oct. 23, 1903).

——Criticism. Ourselves or Our Successors. *Municipal Journal* (London), v. 16, p. 84 (Feb. 1, 1907).

DEPRECIATION; by George Johnson. *Electrical Review* (London), v. 66, p. 1048 (June 24, 1910). (Discusses methods of providing for shrinkage in value; two pages.)

DEPRECIATION; by H. E. McJilton. *Street Railway Journal*, v. 13, p. 288 (May, 1897). (Definition of the word depreciation; what should and what should not be charged to depreciation; abstract of paper read before the Association of Street Railway Accountants; very brief.)

DEPRECIATION; by Patterson J. Logan. *Municipal Journal* (London), v. 15, p. 93 (Jan. 26, 1906). (Depreciation as a factor in the accounts of municipalities and methods of making provision for it.)

DEPRECIATION; by Rowland Wilson. *Mechanical Engineer*, v. 27, p. 309 (March 10, 1911). (On depreciation in relation to works on factory buildings, machinery and plants; one paragraph.)

DEPRECIATION. (Letters); by Thomas G. Milner and Oswald W. Arnold. *Municipal Journal* (London), v. 12, p. 824 (Sept. 11, 1903). (Brief opinions in regard to depreciation in municipal undertakings.)

DEPRECIATION; by W. A. J. O'Meara. *Electrician*, v. 64, p. 1072 (April 8, 1910). (Discusses physical decay, obsolescence, inadequacy, tenure of holding, etc., and the life of machinery and other plant; three pages.)

DEPRECIATION: A PLEA FOR THE STUDY AND USE OF BETTER METHODS; by P. D. Leake. *Mechanical Engineer*, v. 20, pp. 117, 147, 179 (July 27, Aug. 3, 10, 1907). (A plea for better methods of measuring and providing for depreciation of industrial plants.)

DEPRECIATION AND APPRAISALS. (Editorial.) *Electrical Review and Western Electrician*, v. 59, p. 155 (July 22, 1911). (On method of providing for depreciation.)

DEPRECIATION AND PUBLIC SERVICE REGULATION; by Robert H. Whitten. *Engineering News*, v. 69, p. 942 (May 8, 1913). (Straight-line method, accrued depreciation deducted; uniform annual investment cost method, comparison of chief methods; diagram of combined interest and depreciation percentage under each method.)

DEPRECIATION AND RESERVES; by George Wilkinson. *Electric Railway Review*, v. 17, p. 491 (April 13, 1907). (Paper read before the Wharton School of Commerce and Finance.)

——Editorial. *Electric Railway Review*, v. 17, p. 481 (April 13, 1907).

DEPRECIATION AND SINKING FUNDS. (Editorial.) *Municipal Engineering*, v. 38, p. 33 (Jan., 1910). (Three pages.)

DEPRECIATION AND VALUES. (Editorial.) *Municipal Journal* (London), v. 16, p. 304 (April 12, 1907). (Statement by the Electrical Engineer at Southwark that depreciation allowances should be included in sinking fund.)

DEPRECIATION AS AFFECTING ENGINEERING STRUCTURES; by Horatio A. Foster. *Proceedings*, Engineers' Club of Philadelphia, v. 19, p. 330 (Oct., 1902). (Contains tables on effects of depreciation at different rates for term of years, sinking fund, reserve fund, etc; eighteen pages.)

DEPRECIATION ESTIMATES; by Edwin Gruhl. *Aera*, v. 1, p. 644 (March, 1913). (Advocates the necessity of securing actual data as to variation of life in service as a basis for estimating depreciation.)

DEPRECIATION IN ITS RELATION TO APPRAISALS; by Frank F. Fowle. *Electrical World*, v. 56, p. 796 (Oct. 6, 1910). (Address before the Electric Club of Chicago; one page.)

DEPRECIATION OF BUILDINGS AND MACHINERY. *Engineering Record*, v. 63, p. 159 (Feb. 11, 1911). (Two pages.)

THE DEPRECIATION OF FACTORIES, MINES AND INDUSTRIAL UNDERTAKINGS and Their Valuation; by Ewing Matheson. Edition 4. E. & F. N. Spon, Ltd., London, 1910. (Contains six chapters on valuation.)

GENERAL—(*Continued*).

THE DEPRECIATION OF PLANT, AND ITS RELATION TO GENERAL EXPENSE; by H. M. Norris. *Engineering Magazine,* v. 16, pp. 812, 957; v. 17, p. 76 (Feb., March, April, 1899). (On the depreciation of machinery and machine tools; contains a table on the effects of depreciation at different rates for a term of years.)

DEPRECIATION OF PLANT AND WORKS UNDER MUNICIPAL AND COMPANY Management; by Charles H. W. Biggs. *Transactions,* Society of Engineers, 1902, p. 271. (Considers capital, depreciation and maintenance.)

DEPRECIATION OF PUBLIC UTILITIES. *Municipal Journal and Engineer,* v. 22, p. 148 (Feb. 13, 1907). (Methods of allowing for depreciation; one column.)

THE DEPRECIATION PROBLEM; by John L. Bronson. *Cassier's Magazine,* v. 28, p. 190 (July, 1905). (A very short article.)

DEPRECIATION RESERVE. *Municipal Journal and Engineer,* v. 27, p. 772 (Nov. 24, 1909). (Census Bureau's definition of depreciation, and argument of a Public Accountant for a reserve fund derived from income.)

DEPRECIATION RESERVE AND THE PEOPLE. (Editorial.) *Public Service,* v. 5, p. 2 (July, 1908). (Effect of depreciation on rates.)

DEPRECIATION, SHALL SINKING FUND PERIODS BE EXTENDED? by S. H. Turner. *Municipal Journal* (London), v. 12, p. 833 (Sept. 18, 1903). (Abstract of paper read before the British Association.)

——Editorial. *Municipal Journal* (London), v. 12, p. 818 (Sept. 11, 1903).

DETERMINATION OF PHYSICAL VALUES; by Clinton S. Burns. *Engineering Record,* v. 52, p. 328 (Sept. 16, 1905). (Discusses the mathematical determination of values, with examples from water-works plants.)

——*Engineering News,* v. 52, p. 328 (Sept. 16, 1905).

DEVELOPMENT EXPENSE IN THE VALUATION OF PUBLIC SERVICE PROPERties. (Letter); by W. H. Winslow. *Engineering and Contracting,* v. 35, p. 697 (June 14, 1911). (Includes summary of case and editorial comments; one page.)

DIFFICULT PROBLEMS WHICH PUBLIC UTILITY COMMISSIONS ARE ENDEAVORing to Solve; by H. C. Abell. *Journal of Electricity, Power and Gas,* v. 22, p. 81 (Jan. 30, 1909). (Analysis of elements of valuation of public utilities.)

ELEMENTS OF A CONSTRUCTIVE FRANCHISE POLICY; by Delos F. Wilcox. *Engineering News,* v. 64, p. 615 (Dec. 8, 1910). (Abstract of paper read before the National Municipal League of Buffalo.)

ENGINEERING VALUATION OF PUBLIC UTILITIES AND FACTORIES; by Horatio A. Foster. D. Van Nostrand Co., New York, 1912. (Analysis of the elements of valuation; 345 pages.)

EQUITABLE RATE-MAKING BY PUBLIC SERVICE COMPANIES; by Dugald C. Jackson. *Technology Quarterly,* v. 31, p. 348 (Dec., 1908). (Considers depreciation in respect to "obsolescence" and "required reconstruction".)

——*Public Service,* v. 7, pp. 145, 189 (Nov., Dec., 1909).

——*Stone and Webster Public Service Journal,* v. 5, p. 104 (Dec., 1909).

ERROR IN FIGURING DEPRECIATION. (Letter); by C. J. West. *Engineering-Contracting,* v. 32, p. 506 (Dec. 8, 1909). (Depreciation in the Boston Municipal Machine Shop; one column.)

THE ETHICS OF ALLOWANCES FOR DEPRECIATION; by L. S. Randolph. *Engineering Magazine,* v. 39, p. 692 (Aug., 1910). (Discusses three possible general policies and their physical and financial effects; four pages.)

EXPENSE BURDEN, ITS INCIDENCE AND DISTRIBUTION; by Sterling H. Bunnell. *Transactions,* American Society of Mechanical Engineers, v. 33, p. 535 (1911). (Analysis of value of plant and equipment and cost-keeping.)

FACTORY DEPRECIATION, THE PROBLEM OF CORRECT VALUATION; by Ewing Matheson. *Cassier's Magazine,* v. 23, p. 140 (Nov., 1902). (Discussion of the principles involved in valuation.)

FINANCIAL COSTS THAT FREQUENTLY ARE UNDERESTIMATED. *Engineering and Contracting,* v. 37, p. 255 (March 6, 1912). (Organization, taxes, brokerage, interest and development costs or going value.)

FIVE IMPORTANT DECISIONS RELATING TO DEVELOPMENT EXPENSE OR Going Value Based on the Deficit Theory. (Editorial.) *Engineering and Contracting,* v. 36, p. 369 (Oct. 11, 1911). (One and one-half pages.)

FIXED CHARGES IN THE MACHINE SHOP AND DEPRECIATION OF MACHINE Tools; by Henry Spencer. *Engineer,* v. 114, p. 321 (Sept. 27, 1912).

FORM OF GENERAL BALANCE SHEET STATEMENT FOR CARRIERS BY WATER as Prescribed by the Interstate Commerce Commission, First Issue, Effective on Jan. 1, 1913. Government Printing Office, Washington, 1912.

GENERAL—(*Continued*).

GOING VALUE. (Editorial.) *Electrical Review and Western Electrician*, v. 59, p. 2 (July 1, 1911). (Largely extracts from an article by W. J. Hagenah published in *The Voter* entitled "The Regulation of Public Utilities".)

GOING VALUE; by Frank F. Fowle. *Journal*, Western Society of Engineers, v. 17, p. 147 (Feb., 1912). (Review and discussion of the more prominent methods of determining going value, with particular reference to their application to public utilities.)

——Abstract. *Electric Railway Journal*, v. 38, p. 1115 (Nov. 25, 1911).

GOING VALUE AS AN ELEMENT IN THE APPRAISAL OF PUBLIC UTILITY PROPerties; by William H. Bryan. *Journal*, Association of Engineering Societies, v. 43, p. 147 (Oct., 1909). (Discusses intangible values in appraisement of public utility plants; eleven pages.)

——Abstract. *Engineering-Contracting*, v. 32, p. 549 (Dec. 22, 1909).

GOING VALUE OF PUBLIC UTILITIES. (Editorial.) *Electrical World*, v. 57, p. 821 (April 6, 1911). (One page.)

HANDBOOK OF COST DATA FOR CONTRACTORS AND ENGINEERS; by Halbert P. Gillette. Edition 2. Myron C. Clark Publishing Co., Chicago, 1910. (Contains a chapter on principles of engineering economics and cost keeping.)

HEARINGS BEFORE THE COMMITTEE ON IRRIGATION OF ARID LANDS OF THE House of Representatives, April 23, June 1 and 8, 1910, p. 105. Government Printing Office, Washington, 1910. (Contains two and one-half pages on depreciation.)

THE IMPORTANCE OF DEPRECIATION ALLOWANCES. (Editorial.) *Engineering Record*, v. 55, p. 703 (June 15, 1907). (One page.)

INCOME TAX AND DEPRECIATION. *Municipal Journal* (London), v. 16, p. 744 (Aug. 13, 1907). (Allowance for depreciation of plant and machinery by municipalities.)

INTANGIBLE ASSETS OF PUBLIC UTILITIES; by N. I. Garrison. *Public Service*, v. 12, p. 105 (March, 1912). (On values that are not represented by physical property.)

AN INTANGIBLE VALUE. (Editorial.) *Electric Railway Journal*, v. 34, p. 1047 (Nov. 20, 1909). (Discussion of the values that should be allowed above the actual physical property of a public utility; one page.)

INVENTORY VALUATION OF MACHINERY PLANT; by Oberlin Smith. *Transactions*, American Society of Mechanical Engineers, v. 7, p. 433 (1886). (Cost, going value, obsolescence, cost of reproduction as factors in the valuation of machinery.)

THE JUST VALUE OF MONOPOLIES, AND THE REGULATION OF THE PRICES of Their Products; by Joseph Mayer. *Transactions*, American Society of Civil Engineers, v. 75, p. 455 (Paper 1225. Dec., 1912). (Valuation of enterprises supplying transportation, communication, light, heat and power.)

KEEPING DEPRECIATION RECORDS. (Editorial.) *Engineering Record*, v. 52, p. 82 (July 22, 1905). (One column.)

LECTURE NOTES ON SOME OF THE BUSINESS FEATURES OF ENGINEERING Practice, pp. 96, 133; by Alexander C. Humphreys. Stevens Institute of Technology, Hoboken, N. J., 1905. (Contains lectures on repairs and depreciation and on accounting as applied to depreciation.)

——Supplement No. 1, p. 41. Hoboken, N. J., 1905. (Contains supplementary note on depreciation.)

LORD AVEBURY AND DEPRECIATION. (Editorial.) *Municipal Journal* (London), v. 16, p. 112 (Feb. 8, 1907).

THE MAINTENANCE AND OBSOLESCENCE CHARGES. (Editorial.) *Engineering Record*, v. 55, p. 584 (May 11, 1907). (Statement that classification of items under this head might give rise to uncertainty, and example in report of United States Steel Corporation.)

MAY RESERVE FUND TO RENEW OBSOLETE EQUIPMENT. (Editorial.) *Electric Traction Weekly*, v. 6, p. 1473 (Dec. 3, 1910). (Decision of the Supreme Court on the valuation of special franchises.)

METHODS OF COMPUTING DEPRECIATION. (Letter); by Halbert P. Gillette. *Electrical World*, v. 60, p. 1273 (Dec. 14, 1912). (Refers to "unit-cost" depreciation problem.)

METHODS OF DETERMINING LIFE OF PUBLIC UTILITIES. *Engineering and Contracting*, v. 38, p. 448 (Oct. 23, 1912). (Based on a paper by Halford Erickson on depreciation, read before the Central States Water Works Association.)

GENERAL—(*Continued*).

METHODS OF MAKING COMPUTATIONS FOR DEPRECIATION IN PUBLIC UTILITY Plants. (Letter); by F. C. Finkle. *Engineering-Contracting*, v. 34, p. 590 (Oct. 12, 1910). (Challenging the statement that the sinking fund method is in common use to provide for depreciation of public utility plants.)

METHODS OF PROCEDURE UNDER THE WISCONSIN UTILITY LAW, BENEFITS and Restrictions of the Law. *Engineering and Contracting*, v. 38, p. 425 (Oct. 16, 1912). (Discusses methods of valuation, depreciation and business or going value; very brief.)

METHODS OF PROVIDING FOR AND RECORDING DEPRECIATION. *Engineering and Contracting*, v. 38, p. 506 (Nov. 6, 1912). (Various methods of providing for and recording depreciation with special reference to the practice of the Wisconsin Railroad Commission.)

METHODS OF WISCONSIN COMMISSION FOR THE VALUATION OF PUBLIC UTILities. *Electrical World*, v. 54, p. 600 (Sept. 9, 1909).

MUNICIPAL FRANCHISES, v. 2, p. 780; by Delos F. Wilcox. Engineering News Publishing Co., New York, 1911. (Contains a chapter on capitalization, capital value, appraisals and purchase price.)

MUNICIPAL LOAN PURPOSES AND PERIODS IN ENGLAND AND THE UNITED States. (Editorial.) *Engineering News*, v. 54, p. 462 (Nov. 2, 1905). (On depreciation of public properties; contains table; two pages.)

OBSOLESCENCE AND DECREPITUDE AS FACTORS IN DEPRECIATION. *Municipal Engineering*, v. 43, p. 100 (Aug., 1912).

OBSOLESCENCE IN PUBLIC UTILITY PLANTS. (Editorial.) *Municipal Engineering*, v. 42, p. 182 (March, 1912). (Two pages.)

OFFICIAL VALUATIONS OF PRIVATE PROPERTY; by Frederick W. Whitridge. *Electric Railway Journal*, v. 35, p. 110 (Jan. 15, 1910). (Abstract of an address presented before the American Economic Association; discusses methods of valuation; two and one-half pages.)

THE ORGANIZATION FOR AND METHODS AND RESULTS OF PHYSICAL VALUation in Nebraska; by E. C. Hurd. *Engineering and Contracting*, v. 36, p. 694 (Dec. 27, 1911). (Deals with the valuation of railroad and other public utility properties; two pages.)

OVERHEAD CHARGES; by Mortimer E. Cooley. *Proceedings*, American Electric Railway Accountants Association, v. 15, p. 169 (1911). (Discussion of the elements of value of a non-physical nature which are properly included in the appraisal of a public utility property; three pages.)

——Abstracts. *Electric Railway Journal*, v. 38, p. 877 (Oct. 14, 1911); *Canadian Engineer*, v. 22, p. 630 (May 9, 1912).

——Discussion. *Electric Railway Journal*, v. 38, p. 816 (Oct. 14, 1911).

——Editorial. *Electric Railway Journal*, v. 38, p. 897 (Oct. 21, 1911).

THE PHYSICAL VALUATION DEPARTMENT OF THE NEBRASKA STATE RAILway Commission. *Engineering News*, v. 68, p. 300 (Aug. 15, 1912). (Methods of valuation used by the Nebraska State Railway Commission.)

PHYSICAL VALUATION OF PUBLIC UTILITIES, DEPRECIATION IN ITS RELAtions to Investment, Earnings and Current Value; by R. S. Hale. *Engineering Magazine*, v. 45, p. 161 (May, 1913). (Gives general conclusions; five pages.)

PHYSICAL VALUATIONS; by O. T. Crosby. *Proceedings*, American Electric Railway Association, 1911, p. 368. (Discusses the services of the promoter, ways in which profit in public service enterprises have been limited, and some merits of watered stock.)

——Abstract. *Electric Railway Journal*, v. 38, p. 874 (Oct. 14, 1911). (Three pages.)

——Editorial. *Stone and Webster Public Service Journal*, Nov., 1911, p. 309.

A PRACTICAL DISCUSSION OF DEPRECIATION; by Frank F. Fowle. *Southern Electrician*, v. 42, p. 227 (June, 1911). (Difference of opinion about the theory of actual rate of depreciation.)

THE PRINCIPLES OF VALUING PROPERTY, WITH SPECIAL REFERENCE TO Industrial Enterprises; by Henry K. Rowell. *Journal*, American Society of Mechanical Engineers, v. 34, p. 1275 (Sept., 1912); v. 35, p. 285 (Feb., 1913). (This article has the following sub-divisions: Value of property; tax value; insurance value; fair cash value; commercial value; depreciation; capitalization, and method of valuing a plant.)

——Abstract. *Engineering and Contracting*, v. 38, p. 312 (Sept. 18, 1912).

PUBLIC SERVICE RATES AND DEPRECIATION. (Editorial.) *Electrical Review and Western Electrician*, v. 58, p. 67 (Jan. 14, 1911). (One page.)

QUASI-PUBLIC CORPORATION ACCOUNTING AND MANAGEMENT, p. 77, 181; by John F. J. Mulhall. Corporation Publishing Co., Boston, 1905. (On depreciation; three pages.)

GENERAL—(*Continued*).

REGULATION, VALUATION AND DEPRECIATION OF PUBLIC UTILITIES; by Samuel S. Wyer. Sears & Simpson Co., Columbus, Ohio, 1913. (Contains selected bibliography.)

THE RELATION OF DEPRECIATION TO GROSS EARNINGS. *Engineering-Contracting*, v. 34, p. 130 (Aug. 10, 1910). (Comparison of the effects of depreciation charges upon annual income in the case of gas and electric companies as contrasted with water companies; comments on paper by Leonard Metcalf.)

REPAIRS, RENEWALS, DETERIORATION AND DEPRECIATION OF WORKSHOP Plant and Machinery; by James E. Darbishire. *Proceedings*, Institution of Mechanical Engineers, 1908, p. 797. (Method of treating depreciation, etc.)

***REPORT OF THE NEW YORK PUBLIC SERVICE COMMISSION, SECOND DIS**trict. *Electric Railway Journal*, v. 37, p. 301 (Feb. 18, 1911). (Includes brief report on uniform system of accounts, including depreciation.)

***REPORT OF THE PUBLIC SERVICE COMMISSION FOR THE FIRST DISTRICT** of the State of New York for the Year Ending December 31, 1908, v. 1, p. 401. Albany, 1909. (Report upon uniform systems of accounts for public service corporations, basic principles established and treatment of depreciation and appreciation.)

***REPORT OF THE STATE BOARD OF EQUALIZATION FOR 1911-1912 (CALI**fornia), p. 75, and Supplement. Sacramento, 1912. (Contains general discussion of methods of valuation for public service corporations.)

***REPORT ON LEADING RAILROAD AND PUBLIC SERVICE COMMISSIONS**; by Max Thelen. California Railroad Commission, Sacramento, 1912. (On the organization and work of railroad commissions in Oregon, Washington, Nebraska, Minnesota, Wisconsin, New York, Massachusetts, Maryland, Georgia, Texas, and Oklahoma, including their work in physical valuation of property; very brief.)

RESPONSIBILITIES OF ELECTRICAL ENGINEERS IN MAKING APPRAISALS; by H. M. Byllesby. *Transactions*, American Institute of Electrical Engineers, v. 30, p. 1251 (1911). (Remarks on the rapid and wonderful development of electrical engineering and allied industries and discussion of the proper measurement of values in general.)

——Abstract. *Electric Railway Journal*, v. 38, p. 16 (July 1, 1911).

THE SALES METHOD OF APPRAISING LAND NOT UPHELD BY THE COURTS. (Editorial.) *Engineering and Contracting*, v. 36, p. 677 (Dec. 27, 1911). (One column.)

THE SALES METHOD OF APPRAISING REAL ESTATE. *Engineering and Contracting*, v. 35, p. 751 (June 28, 1911). (Statement to the Wisconsin State Railroad Commission of the use of this method made by W. D. Pence; one and one-half pages.)

THE SALES METHOD, THE EXPERT WITNESS METHOD AND THE CAPITALized Rental Method of Appraising Land. (Editorial.) *Engineering and Contracting*, v. 35, p. 733 (June 28, 1911). (One column.)

SINKING FUND CHARGES; by W. H. Booth. *Tramway and Railway World*, v. 13, p. 349 (April 9, 1903). (Allowance for depreciation and renewals.)

SOME CRITERIA OF VALUE IN PUBLIC SERVICE INDUSTRIES; by Clarence P. Fowler. *Engineering Magazine*, v. 42, p. 873 (March, 1912). (Discussion from the point of view of the investment banker.)

SOME PRINCIPLES ESTABLISHED BY THE WISCONSIN COMMISSION. *Electrical World*, v. 57, p. 221 (Jan. 26, 1911). (Paper by Edwin S. Mack presented to the convention of the Wisconsin Electrical Association; discusses actual total investment, cost of going value and good will.)

——*Electric Traction Weekly*, v. 7, p. 61 (Jan. 21, 1911).

——*Electric Railway Journal*, v. 37, p. 164 (Jan. 28, 1911).

SOMETHING ALONG THE LINE OF PHYSICAL AND INTANGIBLE VALUATION as Covered by Recent Legislation; by Robert B. Rifenberick. *Electric Railway Journal*, v. 41, p. 1163 (June 28, 1913). (Physical and other values, reproduction cost, overhead charges, depreciation, recent legislation and the Detroit appraisal; paper read before the Central Electric Railway Association.)

STATE REGULATION OF LIGHTING ENTERPRISES; by H. L. Doherty. *American Gas Light Journal*, v. 89, p. 92 (July 20, 1908). (Address before the Wisconsin Gas Association, discussing general principles in the valuation of public utilities.)

——Abstract. Doherty on Electrical Rates and Franchises. *Electrical World*, v. 52, pp. 170, 352 (July 25, Aug. 15, 1908).

——Editorial. Valuation of Lighting Systems. *Electrical World*, v. 52, p. 607 (Sept. 19, 1908).

GENERAL—(*Continued*).

TAXATION AND VALUATION; by Henry K. Rowell. *Transactions*, National Association of Cotton Manufacturers, No. 82, p. 175 (April, 1907). (Considers principles of common law relating to taxation, methods of determining values of property, and what may be admitted as evidence to establish values of property from its capacity for valuable use.)

THEORIES OF THE VALUATION OF PUBLIC SERVICE INDUSTRIES. *Municipal Engineering*, v. 43, p. 34 (July, 1912).

A TRUST WITNESS. (Editorial.) *Municipal Journal* (London), v. 12, p. 659 (July 17, 1903). (States that municipalities should be compelled to provide a depreciation fund in addition to a sinking fund; very brief.)

TWO CONFLICTING THEORIES OF VALUATION OF PUBLIC SERVICE COMPAnies; by Halbert P. Gillette. *Engineering and Contracting*, v. 38, p. 648 (Dec. 11, 1912). (Discusses theory of market value and investment value.)

——*Railroad Gazette*, v. 54, p. 55 (Jan. 10, 1913).

THE USE OF DEPRECIATION DATA IN RATE MAKING AND APPRAISAL PROBlems; by Halbert P. Gillette. *Engineering and Contracting*, v. 38, p. 476 (Oct. 30, 1912). (An attempt to make clear the radical difference between actual accrued depreciation and estimated prospective depreciation.)

——*Electrical World*, v. 60, p. 927 (Nov. 2, 1912).

——Editorial. Depreciation. *Electrical World*, v. 60, p. 909 (Nov. 2, 1912).

VALUATION, A FAIR RETURN, AND REASONABLE CAPITALIZATION; by Frederick Royce. *Stone and Webster Public Service Journal*, v. 9, p. 7 (July, 1911). (Seventeen pages.)

VALUATION OF LAND FOR RATE-MAKING PURPOSES. *Electrical Review*, v. 61, p. 1106 (Dec. 14, 1912). (Considers whether original cost or present value should be used in appraisal of land.)

VALUATION OF OPERATING PROPERTIES; by Edgar S. Nethercut. *Electric Railway Journal*, v. 35, p. 945 (May 28, 1910). (Paper read before the Central Electric Railway Association; very general statement; one and one-half pages.)

——Discussion. *Electric Railway Journal*, v. 35, p. 976 (June 4, 1910).

THE VALUATION OF PUBLIC SERVICE CORPORATION PROPERTY; by Henry Earle Riggs. *Transactions*, American Society of Civil Engineers, v. 72, p. 1 (Paper 1190. June, 1911). (300 pages.)

——Abstract. The Reasons For and Methods Employed in Appraising the Value of Railway Properties with Special Reference to the Michigan Valuation. *Engineering-Contracting*, v. 34, p. 534 (Dec. 14, 1910).

——Editorial. Method of Appraising Non-Physical Railway Values. *Engineering-Contracting*, v. 34, p. 517 (Dec. 14, 1910).

VALUATION OF PUBLIC SERVICE CORPORATIONS, LEGAL AND ECONOMIC Phases of Valuation for Rate Making and Public Purchase; by Robert H. Whitten. The Banks Law Publishing Co., New York, 1912. (Valuations made for Governmental purposes by official appraisers, commissions or courts; decisions and reports; bibliography of the subject.)

VALUATION OF PUBLIC SERVICE INDUSTRIES; by Henry C. Adams. *Electric Railway Journal*, v. 35, p. 314 (Feb. 19, 1910). (Abstract of paper read before the American Economic Association; one page.)

VALUATION OF PUBLIC SERVICE PROPERTIES; by L. R. Nash. *Stone and Webster Public Service Journal*, v. 11, p. 241 (Oct., 1912). (A summary of opinions, decisions and methods bearing on valuation.)

VALUATION OF PUBLIC UTILITIES; by Clinton S. Burns. *Municipal Journal and Engineer*, v. 29, p. 744 (Nov. 30, 1910). (Discusses depreciation and present value reducing formulas and explains a new method of appraisement.)

VALUATION OF PUBLIC UTILITIES; by Halford Erickson. no place, 1912. (Address before the Indiana Sanitary and Water Supply Association, Feb. 15, 1912.)

——Abstract. Principles of Valuation of Public Utilities. *Public Service Regulation*, v. 1, pp. 294, 370 (May, June, 1912). (Discussion of original, reproduction, going, franchise and earning values and abnormal conditions.)

VALUATION OF PUBLIC UTILITIES BY THE RAILROAD COMMISSION OF WISconsin. *Electric Railway Journal*, v. 34, p. 393 (Sept. 11, 1909). (Description of methods followed by the Commission; three pages.)

——Methods of Wisconsin Commission for the Valuation of Public Utilities. *Electrical World*, v. 54, p. 600 (Sept. 9, 1909).

VALUATION OF PUBLIC UTILITY PROPERTIES; by Henry Floy. McGraw-Hill Book Co., New York, 1912. (Summary of practice with typical examples.)

VALUATION OF THE PROPERTIES OF PUBLIC UTILITY CORPORATIONS; by Charles Gobrecht Darrach. The Bradford Press, Philadelphia, 1913. (Proposed method of estimating the value of public service companies' properties.)

GENERAL—(*Continued*).

THE VALUATION OF THE PROPERTY OF PUBLIC SERVICE CORPORATIONS. *Engineering Record*, v. 58, p. 274 (Sept. 5, 1908). (General article on methods of making valuations.)

VALUING THE PROPERTY OF PUBLIC UTILITIES; by Harold Almert. *Public Service*, v. 12, p. 65 (Feb., 1912). (General article on the appraisal of public utilities; one and one-half pages.)

WHERE A THEORY FAILS; by R. W. Child. *Stone and Webster Public Service Journal*, v. 2, p. 422 (June, 1911). (Discussion on depreciation of physical property.)

THE WISCONSIN PUBLIC UTILITIES LAW; by B. H. Meyer. *Electric Railway Journal*, v. 33, p. 103 (Jan. 16, 1909). (Discusses valuation in a general way; two pages.)

WISCONSIN PUBLIC UTILITY LAW: ITS OPERATION AND RESULTS; by Charles B. Salmon. *Proceedings*, American Water Works Association, v. 29, p. 168 (1909). (On valuation; two and one-half pages.)

——*Municipal Engineering*, v. 37, p. 27 (July, 1909).

*__WORK OF THE JOINT ENGINEERING STAFF OF THE WISCONSIN TAX AND__ Railroad Commissions; by William D. Pence. *Journal*, Western Society of Engineers, v. 14, p. 73 (Feb., 1909). (Describes fully the work of the staff in physical valuations of railways, street railways and other public utilities.)

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Beloit, Wis.

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AMORTIZATION RULE OF THE NEW YORK PUBLIC SERVICE COMMISSION OF the Second District. *Electrical World*, v. 54, p. 1162 (Nov. 11, 1909). (Computation of amortization of property of the Board of Light Commissioners of Boonville, N. Y.)

Bristol, England.

REPORT BY SIR WILLIAM PREESE ON PROBABLE LIFE OF PLANT AT BRISTOL. *Electrician*, v. 57, p. 704 (Aug. 17, 1906). (Details of estimated life of electrical plants; figures given for various items are those used by L. R. Dicksee in his report.)

——Editorial. Depreciation. *Electrician*, v. 57, p. 702 (Aug. 17, 1906).

Burkhardt Milling & Electric Power Co.

***E. G. ROSS ET AL. VS. BURKHARDT MILLING AND ELECTRIC POWER COM**pany; Decided April 8, 1910. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 5, p. 139. Madison, Wis., 1911. (The value of property and the method of determining values are discussed.)

ELECTRIC LIGHT AND POWER—SPECIAL CASES—(*Continued*).

California.

*UNIFORM CLASSIFICATION OF ACCOUNTS FOR ELECTRIC CORPORATIONS prescribed by the Railroad Commission of the State of California; Adopted Oct. 23, 1912, Effective Jan. 1, 1913. Sacramento, 1912.

Cardiff, Wales.

DEPRECIATION: INTERESTING REPORT FROM CARDIFF. *Municipal Journal.* (London), v. 16, p. 1083 (Dec. 20, 1907). (Allowance for depreciation considered to represent fair wear and tear.)

DEPRECIATION OF CARDIFF ELECTRIC TRAMWAY AND LIGHTING UNDERtakings. *Electric Railway Review,* v. 19, p. 16 (Jan. 4, 1908). (Details of rates of depreciation of equipment are given.)

Cashton, Wis.

*IN RE DETERMINING AND FIXING JUST COMPENSATION TO BE PAID TO THE Cashton Light and Power Company by the Village of Cashton for the Taking of the Property of the Said Company Actually Used and Useful for the Convenience of the Public in Accordance With the Provisions of Chapter 499, Laws of 1907; Submitted Oct. 14, 1908, Decided Nov. 28, 1908. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 3, p. 67. Madison, Wis., 1910. (Discusses going value of public utility plants.)

Chippewa Falls, Wis.

*T. J. CUNNINGHAM ET AL. VS. CHIPPEWA FALLS WATER WORKS AND Lighting Company; In Re Investigation by the Railroad Commission of Wisconsin of Rates Charged by the Chippewa Falls Water Works and Lighting Company; In Re Valuation of the Property of the Chippewa Falls Water Works and Lighting Company; Decided June 14, 1910. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 5, p. 302. Madison, Wis., 1911. (Contains data on the value of the electric plant.)

Chippewa Valley Ry., Light & Power Co.

*IN RE APPLICATION OF THE CHIPPEWA VALLEY RAILWAY, LIGHT AND Power Company for Authority to Change its Rates; Submitted Feb. 19, 1908, Decided Mar. 18, 1908. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 2, p. 311. Madison, Wis., 1909. (Refers to valuation of electric plant.)

Darlington, Wis.

*IN RE APPLICATION OF THE DARLINGTON ELECTRIC LIGHT AND WATER Power Company for Power to Increase Rates; In Re Darlington Electric Light and Water Power Company, Valuation of Property; Submitted Sept. 2, 1909, Decided June 17, 1910. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 5, p. 397. Madison, Wis., 1911.

District of Columbia.

*UNIFORM SYSTEM OF ACCOUNTS FOR GAS CORPORATIONS AND ELECTRIC Corporations in the District of Columbia as Prescribed by the Interstate Commerce Commission, pp. 29, 47, 55, 67. Washington, 1909. (Provision for amortization of plant, which includes monthly charges of the amount estimated to be necessary to cover wear, tear and obsolescence.)

Dodgeville, Wis.

*CITY OF DODGEVILLE VS. DODGEVILLE ELECTRIC LIGHT AND POWER COMpany; Submitted May 4, 1908, Decided June 2, 1908. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 2, p. 392. Madison, Wis., 1909. (Data relating to valuation of plant.)

Edinburgh, Scotland.

DEPRECIATION, ETC., ON ELECTRICITY SUPPLY UNDERTAKINGS. *Electrician,* v. 57, pp. 231, 350 (May 25, June 15, 1906). (Report on present condition of electric light and machinery plant of the Edinburgh Corporation.)

Fareham, England.

DEPRECIATION. (Editorial.) *Electrician,* v. 62, p. 709 (Feb. 19, 1909). (Depreciation in connection with a loan for an electrical plant at Fareham, England.)

Greenwood, Miss.

REPORT OF THE APPRAISERS SELECTED TO ESTIMATE THE VALUE OF property of the Greenwood Light and Water Company to the City of Greenwood and the Greenwood Light and Water Co., March 22, 1904. Greenwood, Miss., 1904. (Eight pages.)

Groton, Mass.

A VALUABLE MUNICIPAL RATE DECISION. (Editorial.) *Engineering Record,* v. 66, p. 2 (July 6, 1912). (Comments on decision by the Massachusetts Gas and Electric Light Commission on electrical rates at Groton, Mass; very brief.)

ELECTRIC LIGHT AND POWER—SPECIAL CASES—(*Continued*).

Kaukauna, Wis.

*IN RE DETERMINING AND FIXING THE JUST COMPENSATION TO BE PAID to the Kaukauna Gas, Electric Light and Power Company by the City of Kaukauna; Submitted Feb. 6, 1911, Decided Dec. 26, 1911. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 8, p. 409. Madison, Wis., 1912. (Physical value and going value of the property and value of the water-power lease.)

La Crosse, Wis.

*IN RE APPLICATION OF THE LA CROSSE GAS AND ELECTRIC COMPANY FOR Authority to Increase Its Rates; Decided Nov. 17, 1911. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 8, pp. 138, 156, 170, 179, 202, 224. Madison, Wis., 1912. (Physical value of plants, original cost and effect of allowance of going value.)

*IN RE APPLICATION OF THE LA CROSSE GAS AND ELECTRIC COMPANY FOR Authority to Increase Rates; Submitted Aug. 16, 1907, Decided Sept. 19, 1907. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 2, p. 3. Madison, Wis., 1909. (Gives method of estimating cost of plant before physical examination can be made.)

*THE MEANING OF "ACTUAL STATION OPERATING COSTS." *Engineering Record*, v. 65, p. 191 (Feb. 17, 1912). (Decision of the Railroad Commission of Wisconsin in the case of the La Crosse Gas & Electric Co.)

Madison, Wis.

RATE MAKING FOR PUBLIC UTILITIES, THE MADISON CASE; by Percy H. Thomas. *Electric Journal*, v. 7, p. 560 (July, 1910). (Discusses the decision of the Railroad Commission of Wisconsin in the case of the State Journal Printing Co. *vs.* the Madison Gas & Electric Co., rendered March 8, 1910.)

Manitowoc, Wis.

*CITY OF MANITOWOC VS. MANITOWOC ELECTRIC LIGHT COMPANY; Submitted Sept. 30, 1908, Decided June 14, 1910. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 5, p. 361. Madison, Wis., 1911. (A tentative valuation of the physical property of the respondent was made; the income accounts and operating expenses for a term of years are analyzed.)

Marinette, Wis. See Menominee, Wis.

Marquette, Mich.

A STUDY IN CENTRAL-STATION FINANCES AND OPERATION FROM MARQUETTE, Mich. *Electrical World*, v. 53, p. 403 (Feb. 11, 1909). (Gives estimates of depreciation for an electric light and power plant.)

Massachusetts.

DISTRIBUTION COSTS IN SEVEN CENTRAL-STATION SYSTEMS. *Electrical World*, v. 52, p. 1014 (Nov. 7, 1908). (Figures deduced from returns to the Massachusetts Board of Gas and Electric Light Commissioners.)

Menominee, Wis.

*IN RE VALUATION OF ELECTRIC LIGHT PLANT OF MENOMINEE AND MARInette Light and Traction Company; In Re Application of Menominee and Marinette Light and Traction Company for Authority to Equalize Rates; In Re Menominee and Marinette Light and Traction Company, Investigation of Rates on Motion of the Commission; Decided Aug. 3, 1909. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 3, p. 778. Madison, Wis., 1910. (Data on valuation of electric light and power plant.)

Merrill Ry. & Lighting Co.

*IN RE APPLICATION OF THE MERRILL RAILWAY AND LIGHTING COMPANY for Authority to Change Its Rates for Electric Lighting; Submitted Sept. 17, 1907, Decided Dec. 10, 1907. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 2, p. 148. Madison, Wis., 1909. (Discusses value of the plant, including water power and dam, electric light plant, and railway plant.)

Minneapolis, Minn.

ELECTRIC RATES FOR MINNEAPOLIS, A LONG CONTROVERSY OVER BASING Rates on Expert Analysis or Unreasonable Comparisons; by William G. Deacon. *Public Service*, v. 5, p. 107 (Oct., 1908). (Contains very brief data on valuation.)

MINNEAPOLIS LIGHT AND POWER RATES. *Electrical World*, v. 51, p. 651 (March 28, 1908). (Brief data on the elements of cost of plant.)

ELECTRIC LIGHT AND POWER—SPECIAL CASES—(*Continued*).

New York City.

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PACIFIC GAS RATE VALUATION; by John A. Britton. *Progressive Age*, v. 30, p. 330 (April 15, 1912). (Includes cost of electric energy, depreciation and administration.)

Pasadena, Cal.

PASADENA MUNICIPAL LIGHTING PLANT. *Municipal Engineering*, v. 44, p. 505 (June, 1913). (Capitalization, depreciation allowance, etc., in relation to rate regulation.)

Red Cedar Valley, Wis.

***IN RE APPLICATION OF THE RED CEDAR VALLEY ELECTRIC COMPANY FOR** Authority to Increase its Rates; Decided June 14, 1911. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 6, p. 717. Madison, Wis., 1912. (Contains Company's statement of the value of the physical property of the plant.)

Ripon, Wis.

***CITY OF RIPON VS. RIPON LIGHT AND WATER COMPANY**; Decided March 28, 1910. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 5, p. 1. Madison, Wis., 1911. (Data on vaulation of the water, light and electric plants.)

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REPORT OF ST. LOUIS PUBLIC SERVICE COMMISSION TO THE MUNICIPAL Assembly of St. Louis on Rates for Electric Light and Power. St. Louis, 1911. (Contains description of methods of appraisal of the property of the Union Electric Light & Power Co.)

San Francisco, Cal.

UNIT GENERATING AND DISTRIBUTION COSTS OF THE PACIFIC GAS & ELECtric Company in San Francisco. *Electrical World*, v. 59, p. 790 (April 13, 1912).

Sheboygan, Wis.

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***ESTIMATING THE RATE OF "REASONABLE RETURN" FOR A PUBLIC UTILITY.** *Engineering and Contracting*, v. 39, p. 482 (April 30, 1913). (Argument submitted to the Wisconsin Railroad Commission, for the Superior Water, Light & Power Co., giving analysis of the rate of fair return for capital invested.)

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FAIR RATES FOR PUBLIC SERVICE. (Letter.) *Engineering Record*, v. 59, p. 699 (May 29, 1909). (Decision of Iowa Supreme Court on valuation of the Cedar Rapids Gas Light Co.)

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District of Columbia.

***UNIFORM SYSTEM OF ACCOUNTS FOR GAS CORPORATIONS AND ELECTRIC** Corporations in the District of Columbia as Prescribed by the Interstate Commerce Commission, pp. 29, 47, 55, 67. Washington, 1909. (Provision for amortization of plant, which includes monthly charges of the amount estimated to be necessary to cover wear, tear and obsolescence.)

Galesburg, Ill.

THE GAS FIGHT AT GALESBURG. *Public Service,* v. 4, p. 67 (March, 1908). (Report by Byllesby & Co. on the valuation of the gas plant at Galesburg, Ill.)

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***IN RE INVESTIGATION, ON MOTION OF THE COMMISSION, OF THE RATES,** Rules and Regulations of the Madison Gas and Electric Company; Decided July 5, 1911. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 7, p. 152. Madison, Wis., 1912. (Gives cost of reproduction new and existing value of the Madison gas and electric lighting plant.)

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Manitowoc, Wis.

*IN RE APPLICATION OF THE MANITOWOC GAS COMPANY FOR AUTHORITY to Equalize Rates; Submitted Sept. 28, 1908, Decided Dec. 17, 1908. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 3, p. 163. Madison, Wis., 1910. (Data on the physical valuation of the property.)

*PHILOSOPHY OF GAS RATES, DECISION OF WISCONSIN RAILROAD COMMISSion Authorizing Manitowoc Gas Company to Increase Its Rates. *Public Service*, v. 6, p. 58 (Feb., 1909). (Contains brief reference to depreciation.)

Neenah, Wis.

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New Jersey.

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Passaic, N. J.

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*CITY OF RACINE VS. RACINE GAS LIGHT COMPANY; Decided Jan. 27, 1911. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 6, p. 229. Madison, Wis., 1912. (A tentative valuation of the physical property of the Racine Gas Light Co., including land, breakwater, mains and paving, and the going value of the plant.)

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THE ASSIGNMENT OF VALUATION OF FACILITIES TO MORE THAN ONE STATE. *Engineering and Contracting,* v. 39, p. 726 (June 25, 1913). (A plan for apportioning value of general railroad shops between States; abstract of paper by Hugh H. Bryant read before the Mississippi Valley States Conference.)

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DETERMINING A REASONABLE RATE. (Editorial.) *Railway World*, v. 56, p. 344 (April 19, 1912). (Comments on opinion of Judge Thomas G. Jones, of Alabama, on the cost of reproduction of a railroad, the basis for reasonable rates.)

DEVELOPMENT OF THE FREIGHT RATE HEARING REGARDING THE PHYSICAL Valuation of Railways. (Editorial.) *Engineering-Contracting*, v. 34, p. 263 (Sept. 28, 1910). (One and one-half columns.)

DISCUSSION OF REPORT OF COMMITTEE ON RATES AND RATE MAKING; by M. R. Maltbie. *Proceedings*, Annual Convention of the National Association of Railway Commissioners, 1910, pp. 200, 204. (On "market value," depreciation, and methods of making valuation; five pages.)

THE ECONOMICS OF RAILROAD CONSTRUCTION, p. 41; by Walter Loring Webb. John Wiley & Sons, New York, 1906. (Contains a chapter on the valuation of railway property.)

EQUIPMENT ACCOUNT FOR EACH CAR AND LOCOMOTIVE. *Railway Age Gazette*, v. 43, p. 640 (Nov. 29, 1907). (Method of keeping a depreciation account.)

ESTIMATING THE VALUE OF RAILROAD PROPERTY. *Railroad Gazette*, v. 37, p. 289 (Sept. 2, 1904). (On general principles of valuation; two columns.)

FAIR RETURN ON THE VALUE OF PROPERTY: A FALLACIOUS STANDARD. *Railway Age Gazette*, v. 48, p. 1129 (May 6, 1910). (From an address by Walker D. Hines before the Traffic Club of Pittsburgh.)

FEDERAL REGULATION OF RAILROAD SECURITIES AND VALUATION OF RAILroad Properties; by Henry Fink. *Railway World*, v. 55, p. 390 (May 19, 1911). (Further extracts from statement to the Railway Securities Commission.)

GOVERNMENT SUPERVISION OF RAILWAY ACCOUNTS; by Henry C. Adams. *Electric Railway Review*, v. 19, p. 43 (Jan. 11, 1908). (Abstract of paper read before the Association of American Government Accountants.)

HEARINGS OF THE RAILROAD SECURITIES COMMISSION. (Editorial.) *Railway and Engineering Review*, v. 50, p. 1175 (Dec. 24, 1910). (Refers to question whether valuation of railroad should be used as a basis for issuing new securities.)

HENRY C. ADAMS ON RAILWAY VALUATION. *Railway World*, v. 51, p. 467 (June 7, 1907). (A brief analysis of the elements of valuation.)

HENRY FINK ON DANGER OF RAILWAY VALUATION. *Railway Age*, v. 43, p. 680 (April 26, 1907). (Declares there is no relation between valuation and rate regulation.)

INCOME ACCOUNT OF RAILWAYS. (Letter); by Frank May. *Railway Age*, v. 45, p. 560 (April 17, 1908). (How depreciation charges should be made.)

INITIAL COST, COST OF MAINTENANCE AND DEPRECIATION OF WOODEN Passenger Cars. *Engineering-Contracting*, v. 34, p. 215 (Sept. 7, 1910). (Rate of depreciation per year of different classes of cars.)

LET THE GOVERNMENT GO AHEAD AND PROSECUTE AND APPRAISE THE Railways. (Editorial.) *Railway Age Gazette*, v. 49, p. 566 (Sept. 30, 1910). (Relation between valuation and rates.)

MAINTENANCE CHARGES AND DIVIDENDS. (Editorial.) *Engineering Record*, v. 55, p. 86, (Jan. 26, 1907). (Alludes to comparison of repair costs in relation to traffic; one column.)

MAY RESERVE FUND TO RENEW ABSOLUTE EQUIPMENT. (Editorial.) *Electric Traction Weekly*, v. 6, p. 1473 (Dec. 3, 1910). (Decision by Supreme Court; article states that this is a new principle on valuation of special franchises.)

A METHOD OF APPRAISING NON-PHYSICAL RAILWAY VALUES. (Editorial.) *Engineering-Contracting*, v. 34, p. 517 (Dec. 14, 1910). (Comments on paper by Henry Earle Riggs on valuation of public utilities and on the method employed by Prof. Henry C. Adams in valuation of railroads.)

MR. HANSEL ON VALUATION OF RAILWAYS. (Editorials.) *Railway Age*, v. 44, pp. 71, 277 (July 19, Aug. 30, 1907). (On "State Valuation of Railways", by Charles Hansel in *North American Review* for July 5, 1907.)

——Letter. State Valuation of Railroads; by Carl Tombo. *Railway Age*, v. 44, p. 348 (Sept. 13, 1907).

——Letter. State Valuation of Railroads; by Charles Hansel. *Railway Age*, v. 44, p. 281 (Aug. 30, 1907).

NATIONAL VALUATION CONVENTION URGED, CONCERTED ACTION SHOULD BE Taken to Make Appraisal of Railways Economical, Intelligent and Just; by H. Bortin. *Railway Age Gazette*, v. 54, p. 836 (April 11, 1913).

THE NECESSITY OF DEPRECIATION RESERVES; by Henry L. Gray. *Railway Age Gazette*, v. 48, p. 1297 (May 27, 1910). (Two pages.)

RAILROADS—GENERAL—(*Continued*).

——Editorial. Depreciation Reserves. *Railway Age Gazette,* v. 48, p. 1290 (May 27, 1910).

——Letters. Depreciation Reserves. *Railway Age Gazette,* v. 49, p. 66 (July 8, 1910).

NOTES ON THE APPLICATION OF A DEPRECIATION CHARGE IN RAILWAY Accounting; by Frederic A. Delano. *Railway Age,* v. 45, p. 471 (March 27, 1908). (Depreciation of equipment, track, bridges, buildings, shop tools, etc., of the plant as a whole and limit of depreciation.)

OBSOLESCENCE AND DEPRECIATION FOR LOCOMOTIVES. (Editorial.) *Electric Railway Journal,* v. 41, p. 997 (June 7, 1913). (Comparison between steam and electric locomotives.)

PHYSICAL VALUATION AND CAPITALIZATION. *Railway Age Gazette,* v. 50, p. 121 (Jan. 20, 1911). (A statement of Prof. F. H. Dixon, which is said to refute a statement made by Clifford Thorne to the effect that railways in the States where valuations have been made are over-capitalized.)

PHYSICAL VALUATION AND CAPITALIZATION. *Railway World,* v. 55, p. 88 (Feb. 3, 1911). (Material prepared by the Bureau of Railway Economics; four pages.)

PHYSICAL VALUATION OF AMERICAN RAILWAYS. In Railway Library, 1910, p. 395; edited by Slason Thompson. Bureau of Railway News and Statistics, Chicago, 1911.

PHYSICAL VALUATION OF RAILROADS; by William J. Wilgus. *Proceedings,* American Society of Civil Engineers, v. 39, p. 1109 (May, 1913). (Discusses basic principles, land values, inventorying and pricing measureable items, overhead cost, interest during construction, working capital and depreciation.)

——Abstract. Valuation of Steam Railroads. *Railway Age Gazette,* v. 67, pp. 654, 692 (June 14, 21, 1913).

PHYSICAL VALUATION VERSUS RAILROAD RATES; by Henry Fink. *Railway World,* v. 55, p. 288 (April 14, 1911). (Extracts from statement made to the Railway Securities Commission.)

PHYSICAL VALUATIONS AND CAPITALIZATION OF RAILWAYS; by Slason Thompson. *Railway World,* v. 55, p. 1011 (Dec. 16, 1910). (Gives actual appraisals made in various States.)

——*Railway and Engineering Review,* v. 50, p. 1159 (Dec. 17, 1910).

THE PROBLEM OF RAILWAY VALUATION; by Logan G. McPherson. *Railway Age Gazette,* v. 54, p. 1131 (May 23, 1913). (The change in the attitude of the public toward the carriers, and the various difficult questions it has raised.)

PROGRESS OF VALUATION OF RAILWAYS. *Railway Age,* v. 45, p. 103 (Jan. 24, 1908). (Considers the progress in methods of valuation; one page.)

PROPOSED VALUATION OF RAILROAD PROPERTY. (Editorial.) *Railway Age Gazette,* v. 42, p. 293 (March 8, 1907). (Concerning valuation as a basis for rate-making; one and one-half columns.)

RAILROAD ACCOUNTING AND THE HEPBURN LAW; by Arthur C. Graves. *Railroad Age Gazette,* v. 45, pp. 1543, 1597; v. 46, p. 18 (Dec. 11, 18, 1908; Jan. 1, 1909). (A protest against the requirements of the Government in railroad accounting.)

RAILROAD ACCOUNTING UNDER GOVERNMENT SUPERVISION; by M. P. Blauvelt. *Railway Age,* v. 45, p. 702 (May 15, 1908). (Discusses depreciation of equipment and replacement accounts.)

THE RAILROAD PROBLEM, RATES, UNIT COSTS AND EFFICIENCY; by F. Lincoln Hutchins. *Engineering Magazine,* v. 42, pp. 488, 709 (Jan., Feb., 1912). (The paper contains the following divisions: rate-making, unit costs and efficiency, capitalization and regulation.)

RAILROAD TAXATION AND VALUATION; by C. F. Staples. *Proceedings,* Annual Convention of the National Association of Railway Commissioners, 1909, p. 375. (Discusses gross earning and stock and bond methods of valuation; eight pages.)

RAILROAD VALUATION; by William J. Ripley. Ginn & Co., Boston, 1907. (Thirty-three pages.)

RAILROAD VALUATION, REPRODUCTION COST NEW AS A SOLE BASIS FOR Rates; by D. F. Jurgensen. *Journal,* Association of Engineering Societies, v. 49, p. 294 (Dec., 1912). (On method to be used in the valuation of railroads.)

RAILWAY ATTITUDE TOWARD VALUATION OF RAILWAYS. *Railway Age Gazette,* v. 49, p. 1137 (Dec. 16, 1910). (Arguments against a mere physical valuation; one page.)

RAILROADS—GENERAL—(*Continued*).

RAILWAY CAPITAL AND REAL VALUE; by Darius Miller. *Railway World*, v. 55, p. 28 (Jan. 13, 1911). (An article by the President of the Chicago, Burlington & Quincy R. R., in which he gives his views as to the relation between capitalization and rates.)

RAILWAY DEPRECIATION ACCOUNTS; by C. L. Sturgis. *Proceedings*, Annual Convention of the National Association of Railway Commissioners, 1909, p. 392. (Considers depreciation and depreciation accounts in relation to the question of railway regulation.)

——*Railway Age Gazette*, v. 48, p. 944 (April 8, 1910).

——Abstract. *Electric Railway Journal*, v. 34, p. 1224 (Dec. 18, 1909).

RAILWAY DEPRECIATION ACCOUNTS; by W. J. Meyers. *Proceedings*, Annual Convention of the National Association of Railway Commissioners, 1909, p. 403. (Charging repairs and replacements as made, importance of formal depreciation account and consideration of depreciation by companies affected.)

——Abstract. *Electric Railway Journal*, v. 34, p. 1146 (Dec. 4, 1909).

RAILWAY VALUATION AGAIN. *Railway and Engineering Review*, v. 50, p. 1172 (Dec. 24, 1910). (Comments on statement of Judson C. Clements before the Railways Securities Commission; from *New York Sun*, Dec. 3, 1910.)

RAILWAY VALUATION BY THE CENSUS OFFICE. *Railway Age*, v. 37, p. 1103 (June 17, 1904). (On methods of valuation advocated by the Interstate Commerce Commission; one page.)

REPAIRS, RENEWALS, DETERIORATION AND DEPRECIATION OF WORKSHOP Plant and Machinery; by James Edward Darbishire. *Proceedings*, Institution of Mechanical Engineers, 1908, Pts. 3-4, pp. 812, 879. (The discussion of this paper includes remarks upon the depreciation of railway workshops and rolling stock.)

REPORT OF COMMITTEE ON LIFE OF RAILWAY PHYSICAL PROPERTY. *Proceedings*, American Electric Railway Accountants Association, 1912, p. 189. (Contains bibliography on life of physical property of railways and table of depreciation estimates.)

REPORT OF COMMITTEE ON RAILROAD TAXES AND PLANS FOR ASCERTAINing Fair Valuation of Railroad Property. *Proceedings*, Annual Convention of the National Association of Railway Commissioners, 1903, p. 13; 1904, p. 50; 1905, p. 55; 1906, p. 33; 1908, p. 174; 1909, p. 321; 1910, p. 138; 1911, p. 61; 1912, p. 34. (Reports and discussions of varying length on taxation and the best methods of valuation.)

——Abstract of report for 1905. *Railway Age*, v. 40, p. 289 (Sept. 8, 1905).

——Abstract of report for 1910. *Electric Railway Journal*, v. 36, pp. 1062, 1192 (Nov. 26, Dec. 17, 1910); *Railway and Engineering Review*, v. 50, p. 1130 (Dec. 10, 1910.)

——Abstract of report for 1911. *Electric Railway Journal*, v. 38, p. 1026 (Nov. 11, 1911).

——Abstract of report for 1912. *Electric Railway Journal*, v. 40, p. 1065 (Nov. 23, 1912). (Treats of allowance for contingencies, interest during construction, basis for valuation, cost of reproduction new and original investment and fair value.)

——Editorials on report for 1912. Railway Valuation. *Electric Railway Journal*, v. 40, p. 1051 (Nov. 23, 1912); Valuation by the National and the State Governments. *Electric Railway Journal*, v. 40, p. 1139 (Dec. 7, 1912).

REPORT OF THE COMMITTEE ON FEDERAL RELATIONS. *Proceedings*, American Electric Railway Association, 1911, p. 310. (Contains a page on physical valuation of railways.)

——Abstract. *Electric Railway Journal*, v. 38, p. 812 (Oct. 13, 1911).

REPORT OF THE HADLEY SECURITIES COMMISSION. *Railway Age Gazette*, v. 51, p. 1210 (Dec. 15, 1911). (Two pages.)

——Editorial. The Usefulness of a Physical Valuation. *Railway Age Gazette*, v. 51, p. 1203 (Dec. 15, 1911).

SOME DISPUTED POINTS IN RAILWAY VALUATION. (Editorials.) *Railway Age Gazette*, v. 54, pp. 1056, 1118, 1164, 1208 (May 16, 23, 30, June 6, 1913). (On right of way, investment from earnings, depreciation and intangible values.)

——Criticism. Mr. Loweth on Depreciation in Valuation. (Letter); by C. F. Loweth. *Railway Age Gazette*, v. 54, p. 1536 (June 20, 1913). (Criticism on editorial in issue of May 30th, 1913.)

——Editorial. Depreciation in Railway Valuation. *Railway Age Gazette*, v. 54, p. 1535 (June 20, 1913).

SOME NEGLECTED FACTORS OF FAIR VALUATION. (Editorial.) *Railway Age Gazette*, v. 46, p. 441 (March 5, 1909). (Concerning the relation between physical valuations as made by State Commissions and rate regulation.)

RAILROADS—GENERAL—(*Continued*).

STATISTICS AS TO THE LIFE OF STEEL RAILWAY BRIDGES. *Engineering-Contracting*, v. 30, p. 227 (Oct. 7, 1908). (Reference to depreciation of bridges and table showing life of ten railway bridges.)

AN UNSEEN FACTOR IN RAILWAY VALUATION. (Editorial.) *Railway Age Gazette*, v. 50, p. 821 (April 7, 1911). (In regard to the element which represents investment extinct and destroyed in the various railway re-organizations.)

USEFULNESS OF A PHYSICAL VALUATION. (Editorial.) *Railway Age Gazette*, v. 51, p. 1203 (Dec. 15, 1911). (Comments on the report and recommendations of the Hadley Securities Commission; one page.)

THE VALUATION OF AMERICAN RAILWAYS. (Editorial.) *Railway World*, v. 51, p. 410 (May 17, 1907). (Discusses value regarded as original or reproduction cost and as capitalization on the net earnings of the road.)

VALUATION OF PUBLIC SERVICE CORPORATIONS; by W. H. Williams. American Economic Association, New York, 1909. (Discusses the valuation of railroad taxes, rates, capitalization, etc.; fifty-one pages.)

——Abstract. *Electric Railway Journal*, v. 35, p. 76 (Jan. 8, 1910).

VALUATION OF RAILROAD PROPERTY; by Henry Fink. *Railway Age Gazette*, v. 45, pp. 587, 627 (July 24, 31, 1908). (Discusses physical valuation, capitalization and rate-making.)

VALUATION OF RAILROAD PROPERTY FOR LOCAL TAXATION. (Letter.) *Railroad Gazette*, v. 29, p. 863 (Dec. 10, 1897). (Decisions on valuation of railroads, based on opposing principles, cost of reproduction and earning capacity.)

VALUATION OF RAILROADS. (Editorial.) *Railway Age Gazette*, v. 42, p. 730 (May 31, 1910). (History of attempts to fix value of railroad properties, and statement that this cannot be done on a physical basis; one page.)

VALUATION OF RAILWAY PROPERTIES; by Robert Yates. *Railway Age Gazette*, v. 47, p. 975 (Nov. 19, 1909). (Considers a few of the principal elements of construction showing the cost value and depreciated value.)

VALUATION OF RAILWAYS. *Railway Age Gazette*, v. 46, pp. 173, 219, 261, 312 (Jan. 22, 29, Feb. 5, 12, 1909). (Full discussion of valuation in relation to State Railway Commissions, rates, etc.)

VALUATION OF THE RAILWAYS IN THE UNITED STATES; by B. H. Meyer. *Proceedings*, Annual Convention of the National Association of Railway Commissioners, 1904, p. 46. (General principles of valuation; four pages.)

——Abstract. Valuation of the Railways of the United States. *Railway Age*, v. 38, p. 729 (Nov. 18, 1904).

VALUE OF THE RAILROADS AND THEIR CAPITALIZATION; by H. T. Newcomb *Railroad Gazette*, v. 34, p. 671 (Aug. 29, 1902). (Argues that the capital stock of a railroad does not represent its real value; one page.)

VALUING RAILROAD PROPERTY; by Charles Hansel. *Traffic World*, v. 7, p. 735 (April 22, 1911). (Consideration of earning power, franchise and real value as elements of appraisal; address before the Southern Commercial Congress.)

WHAT IS THE VALUE OF A RAILROAD FOR PURPOSES OF TAXATION? by Charles Hansel. *Railroad Gazette*, v. 33, p. 271 (April 19, 1901). (On the work of Prof. M. E. Cooley, who was selected to examine the railroads in the State of Michigan, and on the subject of valuation in general; one page.)

United States Interstate Commerce Commission.

ACCOUNTING FOR DEPRECIATION OF EQUIPMENT. (Editorial.) *Railway Age*, v. 44, p. 36 (July 12, 1907). (Comments on the proposal to require railways to make formal depreciation accounts as outlined in Accounting Circular, No. 8, United States Interstate Commerce Commission.)

ACCOUNTING FOR DEPRECIATION OF EQUIPMENT. (Letter); by W. A. Worthington. *Railway Age*, v. 44, p. 245 (Aug. 23, 1907). (On the classification of the Interstate Commerce Commission.)

CLASSIFICATION OF ACCOUNTS FOR INTERSTATE STEAM ROADS. *Electric Railway Journal*, v. 32, p. 348 (July 25, 1908). (New classifications as of July 1, 1908, supplements to the revised issues prescribed for the fiscal year beginning July 1st, 1907.)

CLASSIFICATION OF OPERATING EXPENSES AS PRESCRIBED BY THE INTERstate Commerce Commission. Third Revised Issue. Government Printing Office, Washington, 1911. (Gives annual per cent. allowed for depreciation.)

CLASSIFICATION OF OPERATING EXPENSES AS PRESCRIBED BY THE INTERstate Commerce Commission for Steam Roads. Third Revised Edition, Effective July 1st, 1908. Government Printing Office, Washington, 1908. (Contains condensed classification of account for small carriers and extended classification for large carriers.)

——Supplement. Government Printing Office, Washington, 1908.

RAILROADS—GENERAL—(*Continued*).

DEPRECIATION AND RENEWALS ACCOUNTS MODIFIED. (Editorial.) *Railway Age*, v. 44, p. 308 (Sept. 6, 1907). (Discussion of Circular 13, Accounting Series, United States Interstate Commerce Commission.)

DEPRECIATION IN RAILWAY ACCOUNTING. (Letter); by H. A. Dunn. *Railway Age*, v. 45, p. 756 (May 29, 1908). (Comments on methods of accounting recommended by the Interstate Commerce Commission.)

EVALUATION OF RAILROADS; by Walter S. McCormack. *Traffic World*, v. 8, p. 511 (Sept. 23, 1911). (States that carriers should be represented in work of the Interstate Commerce Commission.)

FORM OF GENERAL BALANCE SHEET STATEMENT AS PRESCRIBED BY THE Interstate Commerce Commission for Steam Roads. First Revised Issue, Effective June 15th, 1910. Government Printing Office, Washington, 1910.

HEARING ON DEPRECIATION OF EQUIPMENT ACCOUNTS BY INTERSTATE COMmerce Commission. *Electric Railway Journal*, v. 32, p. 236 (July 4, 1908). (Opinion of a Committee of the American Railway Association.)

——Editorial. Depreciation of Equipment Accounts. *Electric Railway Journal*, v. 32, p. 193 (July 4, 1908).

INTERSTATE COMMERCE COMMISSION DESIRE INFORMATION CONCERNING Treatment of Depreciation Accounts. *Railway Age*, v. 45, p. 221 (Feb. 14, 1908). (Questions which should be considered in keeping account of depreciation; abstract of Circular No. 7, Special Report Series.)

OBJECTIONS TO THE DEPRECIATION CHARGE. *Railroad Age Gazette*, v. 45, p. 1050 (Oct. 2, 1908). (A summary of views expressed by railroad officers on depreciation; memorandum of the American Railway Association's Special Committee to the Interstate Commerce Commission.)

——Depreciation in Steam Railway Accounting. *Electric Railway Journal*, v. 32, p. 748 (Oct. 3, 1908).

—— Editorial. Proposed Valuation and Rates. *Railway Age*, v. 43, p. 268 (March 1, 1907).

PROTEST OF PENNSYLVANIA RAILROAD AGAINST CLASSIFICATION OF ADDItions and Betterments. *Electric Railway Journal*, v. 34, p. 908 (Oct. 23, 1909). (Formal protest to the Interstate Commerce Commission against required classification of accounts.)

QUESTIONS PERTAINING TO DEPRECIATION. *Railway Age*, v. 44, p. 805 (Dec. 6, 1907). (Abstracts of Circulars 12 and 12*a*, Accounting Series, United States Interstate Commerce Commission.)

STATE VALUATION OF RAILWAYS; by Darius Miller. *Railway and Engineering Review*, v. 50, p. 1027 (Nov. 5, 1910). (Statements made at the rate hearing of the Interstate Commerce Commission.)

United States Railway Valuation Act.

THE BILL FOR PHYSICAL VALUATION. *Railway and Engineering Review*, v. 53, p. 169 (Feb. 22, 1913). (The text of the Railway Valuation Act.)

——Bill for Physical Valuation of Railways. *Railway Age Gazette*, v. 52, p. 811 (April 5, 1912). (Full text of the Adamson Bill for the physical valuation of railways by the Interstate Commerce Commission.)

CAN ENGINEERS BE TRUSTED TO ARBITRATE FAIRLY AND INTELLIGENTLY Between the Public Interests and the Property Interests? (Editorial.) *Engineering News*, v. 69, p. 1187 (June 5, 1913.) (On statement of Senator Robert M. La Follette that railroad valuation work should be placed in charge of an economist and not of an engineer.)

HEARING ON PROPOSED FEDERAL RAILROAD APPRAISAL. *Railway and Engineering Review*, v. 53, p. 140 (Feb. 15, 1913).

A HUGE PIECE OF ENGINEERING WORK. (Editorial.) *Engineering News*, v. 69, p. 476 (March 6, 1913). (Comments on the Railway Valuation Act.)

PHYSICAL VALUATION OF RAILROADS. (Editorial.) *Railway Age Gazette*, v. 45, p. 1029 (Oct. 2, 1908). (Recommendation for Federal valuation of railroads by Henry C. Adams, Statistician of the Interstate Commerce Commission: one and one-half columns.)

PLAN FOR PHYSICAL VALUATION OF RAILWAY PROPERTIES. *Railway Age*, v. 43, p. 286 (March 1, 1907). (Abstract of a memorandum by H. C. Adams submitted to the President by the Interstate Commerce Commission.)

THE PLANK IN THE DEMOCRATIC PLATFORM PLEDGING THE APPRAISAL OF All Railways. (Editorial.) *Engineering and Contracting*, v. 38, p. 562 (Nov. 20, 1912). (Estimates the cost of a railway appraisal to range from \$2.50 per mile, for very rough inventory, to \$25 per mile for a very thorough appraisal, or about 50 cents per \$1 000 of physical property appraised.)

PROPOSED NATIONAL VALUATION CONVENTION. (Letter); by L. C. Fritch. *Railway Age Gazette*, v. 54, p. 1536 (June 20, 1913). (Objections to holding convention.)

RAILROADS—GENERAL—(*Continued*).

——The Railway Valuation Act. *Engineering News,* v. 69, p. 482 (March 6, 1913). (Text of the law passed by Congress ordering the valuation of railroad properties.)

THE RAILWAY VALUATION ACT. (Letter); by Alex. C. Humphreys. *Engineering News,* v. 69, p. 688 (April 3, 1913). (The doubtful value of the provision of the law which requires the appraisers to analyze past financial transactions of railroads.)

STATE RAILWAY COMMISSIONERS AND FEDERAL VALUATION; by D. F. Jurgensen. *Railway and Engineering Review,* v. 53, p. 529 (June 7, 1913). (States that the Federal valuation is a contest between carriers and public, with the Interstate Commerce Commission as umpire.)

VALUATION OF THE RAILROADS. (Editorial.) *Engineering Record,* v. 67, p. 283 (March 15, 1913). (On the Railway Valuation Act.)

THE VALUE OF VALUATION. (Editorial.) *Electric Railroad Journal,* v. 41, p. 667 (April 12, 1913). (Doubt expressed as to the usefulness of the valuation of railroads provided for by Congress.)

RAILROADS—SPECIAL CASES.

Atchison, Topeka & Santa Fé R. R.

WHY RAILROADS NEED HIGHER RATES, p. 88; by E. P. Ripley. Chicago (?), 1910. (Takes up the physical value of the Santa Fé R. R. in testimony before the Interstate Commerce Commission, Chicago, 1910.)

Beaumont & Great Northern R. R.

VALUATION OF THE RAILWAYS OF TEXAS. *Engineering-Contracting,* v. 33, p. 370 (April 20, 1910). (Detailed value of the Beaumont & Great Northern R. R., with brief comments.)

Boston & Maine R. R.

*EVIDENCE AS TO THE VALUE OF NEW HAMPSHIRE ROADS EMBRACED IN the Boston & Maine System. In the Report of the Public Service Commission of New Hampshire on an Investigation of Railroad Rates, p. 300. Concord, N. H., 1912. (Discussion of formula for determining the value of railroad properties: Original cost; amount and market value of stocks and bonds; present as compared with original cost of construction; probable earning capacity.)

California.

*INSTRUCTIONS TO ASSISTANT ENGINEERS FOR INSPECTING RAILWAY PROPerty for Inventory and Appraisal, California Railroad Commission. *Engineering and Contracting,* v. 37, p. 619 (May 29, 1912).

Chicago, Milwaukee & St. Paul R. R.

*A. E. BUELL VS. CHICAGO, MILWAUKEE & ST. PAUL RAILWAY COMPANY; Submitted July 1, 1906, Decided Feb. 16, 1907. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 1, pp. 337, 478. Madison, Wis., 1908. (Discusses what constitutes a fair valuation of a railroad.)

ITEMIZED COST OF THE C., M. & ST. P. R. R. IN SOUTH DAKOTA. *Engineering-Contracting,* v. 28, p. 56 (July 24, 1907). (Estimates given in the Spokane rate case.)

Great Britain.

THE SERVICEABLE LIFE AND COST OF RENEWALS OF PERMANENT WAY OF British Railways; by R. Price-Williams. *Journal,* Iron and Steel Institute, v. 80, p. 183 (1909, Pt. 2). (Gives actual figures and diagrams of cost of maintenance on British railways for a number of years.)

Great Northern Ry.

ITEMIZED COST OF THE GREAT NORTHERN RAILWAY SYSTEM AS ESTIMATED by Its Chief Engineer. *Engineering-Contracting,* v. 29, p. 271 (May 6, 1908). (Estimates given in testimony before the Interstate Commerce Commission in the Spokane rate case.)

ORIGINAL COST AND COST OF REPRODUCTION OF THE GREAT NORTHERN Railway (768 Miles) in the State of Washington. *Engineering-Contracting,* v. 32, p. 496 (Dec. 8, 1909). (Data as to the original cost, given by Halbert P. Gillette before the Railroad Commission.)

Kansas.

*KANSAS RAILWAY VALUATION, REPORT OF THE WORK OF THE ENGINEERing Department, Public Utilities Commission, from Date of Establishment to Nov., 1912; by C. C. Witt. *Public Service Regulation,* v. 2, p. 217 (May, 1913).

RAILROADS—SPECIAL CASES—(*Continued*).

Kansas City Southern Ry.

ACCOUNTING FOR ABANDONED PROPERTY. *Electric Railway Journal*, v. 39, p. 247 (Feb. 10, 1912). (Reply of Interstate Commerce Commission to the suit brought by the K. C. S. Ry., in regard to manner of accounting for value of property abandoned in the reconstruction of track.)

Louisiana.

***REPORT MADE BY THE STATE BOARD OF APPRAISERS SHOWING THE** Assessments Made of Property Employed in the Railway, Telegraph, Telephone, Sleeping Car, and Express Business for the Year 1899. (On the methods of valuation, and actual valuations made.)

Massachusetts.

THE FRANCHISE IN CAPITALIZATION. (Editorial.) *Railroad Gazette*, v. 37, p. 269 (Aug. 26, 1904). (Discussion of bill presented to Massachusetts Legislature allowing a new corporation to capitalize on a basis of market value of absorbed companies and to capitalize the franchises.)

Michigan.

EXPERT VALUATION OF RAILWAY AND OTHER CORPORATE PROPERTY IN Michigan. *Engineering News*, v. 44, p. 430 (Dec. 20, 1900). (Full account of the valuation made by the Michigan Board of State Tax Commissioners, describing organization for the work.)

RAILROAD TAXATION; by Robert H. Shields. In Sixth Report of the Board of State Tax Commissioners, Dec. 15, 1910, p. 53. Lansing, Mich., 1911. (Discusses several theories for valuation of railroads.)

RAILWAY CAPITAL AND VALUES; by W. H. Williams. *Railway Age Gazette*, v. 46, pp. 761, 805, 845, 903 (April 2, 9, 16, 23, 1909). (Outlines the methods used to obtain a physical valuation of railroad property in Michigan.)

——Abstract. *Railway and Engineering Review*, v. 48, p. 1047 (Dec. 26, 1908).

Minneapolis, St. Paul & Sault Ste. Marie Ry.

***IN RE INVESTIGATION ON MOTION OF THE COMMISSION OF PASSENGER** Rates Charged by the Minneapolis, St. Paul & Sault Ste. Marie Railway Company; Submitted April 9, 1907, Decided June 1, 1907. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 1, pp. 543, 581. Madison, Wis., 1908. (Contains brief reference to valuation of the road.)

Minnesota.

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DEPRECIATION, RESERVES AND SINKING FUNDS; by W. O. Strangward. *Electric Railway Journal*, v. 40, p. 123 (July 27, 1912). (Discusses reserves for depreciation, renewals and obsolescence.)

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ENGINEERING AND ELECTRIC TRACTION POCKET-BOOK, p. 914; by Philip Dawson. Edition 4. John Wiley & Sons, New York, 1906. (Gives various tables including durability of railroad ties and approximate life of various parts of plant.)

EQUITABLE CHARGES FOR TRAMWAY SUPPLY; by H. E. Yerbury. *Journal,* Institution of Electrical Engineers, v. 44, p. 576 (1910). (Valuation cost of street railway plants as a basis for rates.)

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——Abstract. *Electric Railway Journal,* v. 38, p. 766 (Oct. 12, 1911).

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VALUATION OF A SHORT-TERM FRANCHISE. (Editorial.) *Electric Railway Review,* v. 17, p. 313 (March 9, 1907). (Should reconstruction and renewals be charged to capital accounts or provided for out of earnings, etc.)

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WHERE MAINTENANCE ENDS AND DEPRECIATION BEGINS; by J. H. Neal. *Proceedings,* American Street and Interurban Railway Accountants' Association, 1907, p. 195. (Discusses the relation between maintenance and depreciation.)

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INSURANCE FUND AND DEPRECIATION RESERVES. (Letter); by John Blair MacAfee. *Street Railway Review*, v. 15, p. 292 (May 15, 1905). (Plans of the Augusta-Aiken Ry. & Electric Co. for taking care of depreciation.)

Boston Elevated Ry.

HEARING ON ELECTRIC RAILWAY MAIL PAY. *Electric Railway Journal*, v. 41, p. 291 (Feb. 15, 1913). (Details of estimated cost of operation of present type of mail car on Boston Elevated Ry.; car, power, track investment, etc.; includes per cent. allowed for depreciation in each case.)

Brooklyn, N. Y.

ALLOWANCE FOR OBSOLESCENCE UPHELD IN FRANCHISE TAX CASE. *Electric Railway Journal*, v. 36, p. 1154 (Dec. 10, 1910). (Decision of New York Supreme Court in favor of Brooklyn Rapid Transit Co.; one-half page.)

APPROXIMATE VALUE PLACED ON PHYSICAL PROPERTY OF BROOKLYN Transit System. *Electric Railway Journal*, v. 34, p. 1261; v. 35, pp. 156, 248 (Dec. 25, 1909; Jan. 22, Feb. 5, 1910). (Testimony of B. J. Arnold and T. S. Williams before New York Public Service Commission.)

HEARING ON VALUATION OF CONEY ISLAND AND BROOKLYN R. R. *Electric Railway Journal*, v. 34, pp. 377, 398, 437, 469, 878, 1108, 1148, 1188, 1263; v. 35, pp. 104, 460 (Sept. 4, 11, 18, 25, Oct. 16, Nov. 27, Dec. 4, 11, 25, 1909; Jan. 15, March 12, 1910). (Hearing before the New York Public Service Commission, First District.)

MAY RESERVE FUND TO RENEW OBSOLETE EQUIPMENT. *Electric Traction Weekly*, v. 6, p. 1473 (Dec. 31, 1910). (Decisions of the Supreme Court at Albany that there may be a deduction for obsolescence as distinguished from depreciation in connection with the valuation of special franchise of the Brooklyn Rapid Transit Co.)

*RE MacREYNOLDS V. BROOKLYN UNION ELEVATED RAILROAD COMPANY (Case 353). Reports and Decisions of the Public Service Commission, First District of the State of New York, v. 2, p. 246. New York, 1912. (Relation of fares and the valuation of Brooklyn Union Elevated R. R. Co.)

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STREET AND INTERURBAN RAILROADS—SPECIAL CASES—(*Continued*).

Buffalo, N. Y.

DEPRECIATION CHARGES OF THE INTERNATIONAL TRACTION COMPANY. (Editorial.) *Electric Railway Review*, v. 19, p. 472 (April 18, 1908). (The definite policy of the International Traction Co. of Buffalo, in accounting currently for depreciation.)

FURTHER TESTIMONY IN BUFFALO REORGANIZATION CASE; by F. A. Sager. *Electric Railway Journal*, v. 39, p. 246 (Feb. 10, 1912). (Reviews methods followed in the inventory of the physical property of the International Traction Co.)

HEARING IN BUFFALO ON INTERNATIONAL TRACTION REORGANIZATION. *Electric Railway Journal*, v. 38, pp. 910, 991 (Oct. 21, Nov. 4, 1911). (An account of the methods used by B. J. Arnold in determining the cost to produce new the physical property of the International Traction Co. of Buffalo.)

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TRACK DEPRECIATION AT CARDIFF; by John Allcock. *Tramway and Railway World*, v. 27, p. 30 (Jan. 6, 1910). (Brief statement.)

Chicago, Ill.

THE BASIS OF VALUATION IN THE CASE OF MUNICIPAL PURCHASE OF STREET Railways; by Sidney Ossoski. *Electric Railway Journal*, v. 36, p. 999 (Nov. 12, 1910). (Discusses methods of valuation using street railways of Chicago and Cleveland as examples; two pages.)

CHICAGO ELEVATED RAILWAY VALUATION. *Electric Railway Journal*, v. 39, p. 1087 (June 22, 1912). (Elements entering into the value of each piece of property in real estate valuation.)

——Abstracts. Reports of Appraisal of the Physical Properties of the Elevated Railways of Chicago. *Engineering and Contracting*, v. 37 (May 15, 1912); The Valuation of the Elevated Railroads of Chicago. *Engineering Record*, v. 65, p. 552 (May 18, 1912).

——Editorial. *Engineering Record*, v. 65, p. 534 (May 18, 1912). (Very brief.)

CHICAGO ELEVATED RAILWAYS, REPORT ON VALUATION OF PHYSICAL Property Including Real Estate and Rights of Way of the South Side Elevated Railroad Company, Metropolitan West Side Elevated Railway Company, Northwestern Elevated Railroad Company and Chicago & Oak Park Elevated Railroad Company, to the Local Transportation Committee of the City Council of Chicago, April 30, 1912, Reprinted May 9, 1912, with the Addition of the Final Figures of the Valuation Commission; by George F. Swain. Chicago, 1912.

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STREET AND INTERURBAN RAILROADS—SPECIAL CASES—(*Continued*).

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ESTIMATED COST OF CABLE RAILWAYS IN CHICAGO. *Engineering and Contracting,* v. 37, p. 338 (March 20, 1912). (Cost of reproducing cable railway new as estimated by Bion J. Arnold.)

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METHODS OF CONDUCTING THE VALUATION OF THE PHYSICAL PROPERTIES of the Chicago Consolidated Traction Co., with Summaries of Costs; by Philip J. Kealy. *Engineering-Contracting,* v. 34, pp. 274, 295 (Sept. 28, Oct. 5, 1910). (The valuation covers only that portion of the system within the city limits; describes methods and costs of track and power-house valuation and data of the electric power distribution.)

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VALUATION REPORTS ON CHICAGO ELEVATED ROADS. (Editorial Correspondence.) *Electric Traction Weekly,* v. 8, p. 556 (May 11, 1912).

VALUATIONS OF CHICAGO ELEVATED RAILWAYS. *Electric Railway Journal,* v. 39, p. 829 (May 18, 1912). (Detail figures and summaries of the explanatory statements made in connection with the two valuations.)

VALUE OF PROPERTY OF THE CHICAGO CONSOLIDATED TRACTION COMpany. *Electric Railway Journal,* v. 36, pp. 309, 374, 1111 (Aug. 20, Sept. 3, Dec. 3, 1910). (Valuation made by Bion J. Arnold and George W. Weston.)

STREET AND INTERURBAN RAILROADS—SPECIAL CASES—*(Continued)*.

Cleveland, Ohio.

ARBITRATION OF OPERATING EXPENSE CHARGES IN CLEVELAND. *Electric Railway Journal*, v. 41, p. 925 (May 24, 1913). (Includes brief reference to depreciation of the railway plant and maintenance, renewal and depreciation fund.)

DECISION OF ARBITRATOR IN CLEVELAND CONTROVERSY. *Electric Railway Journal*, v. 34, p. 1237 (Dec. 25, 1909). (Findings of Judge Taylor in the Cleveland Street Railway valuation.)

DECISION OF BOARD OF ARBITRATION IN THE CLEVELAND CASE. *Electric Railway Journal*, v. 41, p. 1159 (June 28, 1913). (Text of the finding, including allowance for maintenance, renewal and depreciation.)

—— Editorial. The Arbitrated Result in Cleveland. *Electric Railway Journal*, v. 41, p. 1134 (June 28, 1913).

DEPRECIATION IN CLEVELAND. *Street Railway Journal*, v. 29, p. 743 (April 27, 1907). (On depreciation of track and cars; abstract from report of the Cleveland Electric Ry. Co.)

FINAL TESTIMONY AND ARGUMENTS IN THE CLEVELAND CASE. *Electric Railway Journal*, v. 41, p. 1070 (June 14, 1913). (Depreciation in the value of the property shown by tables submitted by Henry J. Davies.)

MAINTENANCE PROVISIONS OF CLEVELAND ORDINANCE; by H. J. Davies. *Electric Railway Journal*, v. 35, p. 614 (April 2, 1910). (Provisions for maintenance of physical property of Cleveland Ry. Co. determined in granting new franchise ordinance.)

OPERATION OF THE CLEVELAND STREET RAILWAY SYSTEM BY A NEW COMpany. *Electric Railway Journal*, v. 32, p. 433 (Aug. 8, 1908). (Provisions for maintenance and renewal fund in lease.)

TESTIMONY IN CLEVELAND VALUATION. *Electric Railway Journal*, v. 34, pp. 1024, 1068, 1159 (Nov. 13, 20, Dec. 4, 1909). (Opinions on valuation of the Cleveland Street Railway given by Frank R. Ford, Bion J. Arnold and others before Judge Taylor of the United States Circuit Court.)

VALUATION OF THE CLEVELAND ELECTRIC RAILWAY. *Electric Railway Review*, v. 19, p. 149 (Feb. 1, 1908). (Values of physical property, overhead charges, franchises, etc.; two pages.)

Detroit, Mich.

APPRAISAL OF THE CITY LINES OF THE DETROIT UNITED RAILWAY. *Electric Railway Journal*, v. 41, p. 897 (May 17, 1913). (Methods and summary of valuation.)

REPORT AND APPRAISAL OF THE DETROIT UNITED RAILWAY (CITY LINES), Detroit, Michigan, Oct. 1, 1909; by Frederick T. Barcroft. Detroit, 1910. (Contains brief data on method of making appraisal.)

——Abstract. The Appraisal Value of the Electric Street Railways of Detroit, Mich. *Engineering-Contracting*, v. 34, pp. 16, 35 (July 6, 13, 1910).

——Editorial. Noteworthy Article on Electric Street Railway Appraisal. *Engineering-Contracting*, v. 34, p. 1 (July 6, 1910).

REPORT OF THE COMMITTEE OF FIFTY. *Electric Railway Journal*, v. 36, pp. 111, 142 (July 16, 23, 1910). (Abstract of report of Committee to investigate Detroit Street Railway situation; contains brief references to the appraisal.)

REPORTS ON VALUATION OF DETROIT PROPERTY. *Electric Railway Journal*, v. 34, p. 1077 (Nov. 20, 1909). (Brief comparison of the valuations made by F. T. Barcroft and R. B. Rifenberick.)

RESULTS OF DETROIT INVESTIGATION. *Electric Railway Journal*, v. 34, p. 1276 (Dec. 25, 1909). (Concerning reports received by the Committee of Fifty on the street railway valuation.)

A STATEMENT OF "FACTS" CONCERNING THE SO-CALLED "BARCROFT Appraisal" of the Detroit United Railway Lines in the City of Detroit; by R. B. Rifenberick. Detroit, Mich., 1910. (A criticism of Mr. Barcroft's methods.)

THE VALUATION OF THE DETROIT STREET RAILWAYS. *Engineering News*, v. 64, p. 212 (Aug. 25, 1910). (An explanation of the situation with comparison of valuations made for the City with those for the Company; two pages.)

VALUATION OF THE TRACK OF THE DETROIT STREET RAILWAY SYSTEM. *Engineering News*, v. 64, p. 249 (Sept. 8, 1910). (Explains methods used in track valuation, including estimated value of twenty-one types of rail sections; one page.)

VALUATIONS OF THE DETROIT UNITED RAILWAY. *Electric Railway Journal*, v. 36, pp. 258, 294 (Aug. 13, 20, 1910). (Review of the facts, statement of the position of the Company regarding the Barcroft appraisal, brief abstract of the Barcroft appraisal, and a statement by R. B. Rifenberick.)

STREET AND INTERURBAN RAILROADS—SPECIAL CASES—(*Continued*).

Duluth, Minn.

DECISION OF WISCONSIN COMMISSION IN SUPERIOR CASES. *Electric Railway Journal*, v. 40, p. 1067 (Nov. 23, 1912). (Data on valuation of property of Duluth Street Ry. Co.)

Eastern Ry. & Light Co. See Fond du Lac, Wis.

Europe.

DEPRECIATION AS APPLICABLE TO ELECTRIC RAILWAYS; by Haselmann. *Electric Railway Journal*, v. 28, p. 1003 (Nov. 24, 1906). (Abstract of a paper read before the International Street and Interurban Railway Association giving methods of depreciation accounting in Europe; three pages.)

DEPRECIATION FUNDS IN EUROPE. *Electric Railway Journal*, v. 23, p. 696 (May 7, 1904). (Gives allowances made for depreciation.)

——Editorial. Depreciation. *Electric Railway Journal*, v. 23, p. 760 (May 21, 1904).

Fond du Lac, Wis.

*EXISTING FARES OF WISCONSIN ROAD UPHELD BY COMMISSION AFTER A Valuation. *Electric Railway Journal*, v. 38, p. 193 (July 9, 1911). (Valuation of electric railway properties and division of valuation between city and interurban systems; decision of the Railroad Commission of Wisconsin in a fare case involving the Eastern Ry. & Light Co. of Fond du Lac.)

Fonda, Johnstown & Gloversville R. R.

LIFE OF RAILWAY PHYSICAL PROPERTY FROM THE ENGINEERING STAND-point; by F. A. Bagg. *Electric Railway Journal*, v. 38, p. 1205 (Dec. 9, 1911). (Paper read before Street Railway Association of State of New York; discusses life of track and overhead lines and gives data regarding Fonda, Johnstown & Gloversville R. R.; one page.)

——Discussion. *Electric Railway Journal*, v. 38, p. 1210 (Dec. 9, 1911).

Glasgow, Scotland.

DEPRECIATION. (Editorial.) *Electrician*, v. 61, p. 744 (Aug. 28, 1908). (Practice of Glasgow Corporation Tramways.)

GLASGOW AND DEPRECIATION. *Municipal Journal* (London), v. 12, p. 795 (Sept. 4, 1903). (Very brief itemized statement of allowance for depreciation by Glasgow Corporation Tramways.)

GLASGOW TRAMWAYS. *Municipal Journal* (London), v. 14, p. 896 (Aug. 11, 1905). (Analysis of accounts of Glasgow Tramways, including allowance for depreciation.)

TREATMENT OF DEPRECIATION IN GLASGOW. *Electric Railway Journal*, v. 36, p. 362 (Sept. 3, 1910). (Discussion of the treatment of depreciation in accounts in report of the Glasgow Corporation Tramways.)

VALUATION OF GLASGOW TRAMWAYS. *Tramway and Railway World*, v. 27, p. 353 (May 5, 1910). (Decision in the appeal of the Glasgow Corporation Tramways against compulsory valuation.)

Great Britain.

B. E. T. DEPRECIATION. *Municipal Journal* (London), v. 16, p. 449 (May 24, 1907); v. 17, p. 459 (June 5, 1908). (Per cent. allowed for depreciation by sixteen British street railway companies.)

DEPRECIATION AND PERMANENT RENEWAL FUND; by William R. Bowker. *Street Railway Bulletin*, v. 6, p. 298 (May, 1907). (On the amount to be allowed for depreciation in street railroad property, giving cities of Manchester, Glasgow, Leeds, Bolton, and Wolverhampton, as examples.)

POLICY OF ENGLISH MUNICIPAL TRAMWAYS RESPECTING RENEWALS. *Electric Railway Journal*, v. 38, p. 661 (Oct. 7, 1911). (Two pages.)

RULES ON DEPRECIATION IN GREAT BRITAIN. *Electric Railway Journal*, v. 34, p. 476 (Sept. 25, 1909). (Allowances for depreciation in electric railway undertakings; one page.)

Illinois.

REPORT OF THE ILLINOIS TRACTION SYSTEM. (Editorial.) *Electric Railway Journal*, v. 36, p. 353 (Sept. 3, 1910). (Refers to annual allowance for depreciation.)

Kansas City, Mo.

DEPRECIATION CHARGES IN KANSAS CITY. (Editorial.) *Electric Railway Journal*, v. 36, p. 424 (Sept. 17, 1910). (On provision for depreciation made by the Kansas City Ry. & Light Co.; one paragraph.)

REPORT ON STREET RAILWAY SYSTEM OF KANSAS CITY. *Electric Railway Journal*, v. 41, p. 716 (April 19, 1913). (An investigation of the valuation of the property and its apportionment between the different municipalities.)

STREET AND INTERURBAN RAILROADS—SPECIAL CASES—(*Continued*).

REPORT ON THE VALUE OF THE PROPERTIES OF THE METROPOLITAN STREET Railway System of Kansas City, v. 1; by Bion J. Arnold. Kansas City, Mo., 1913. (Report of Commission to investigate the capital value of the properties, various elements of such value, and how it shall be apportioned between the municipalities in a contract for a new franchise.)

A STREET-RAILWAY VALUATION. *Engineering News*, v. 69, p. 1053 (May 22, 1913). (Valuation of the street railway lines of Kansas City, Mo., by Bion J. Arnold; values found and various elements thereof and comparison with the values computed under four different methods.)

Kokomo, Marion & Western Traction Co.

DEPRECIATION ACCOUNT OF THE KOKOMO, MARION & WESTERN TRACTION Company. *Electric Railway Journal*, v. 38, p. 156 (July 22, 1911). (An arbitrary charge of a certain per cent. against each class or division of the property was adopted, to provide for current replacements and future requirements on account of losses due to age and wear; about the same percentages as are used by the Wisconsin Railroad Commission; one page.)

Lincoln, Nebr.

*TESTIMONY ON DEPRECIATION BEFORE NEBRASKA COMMISSION; by Edward W. Bemis. *Electric Railway Journal*, v. 35, p. 441 (March 12, 1910). (Testimony in relation to the consolidation of the properties comprising the Lincoln Traction Co.)

London, England.

LONDON TRAMWAY DEPRECIATION ALLOWANCE FOR INCOME TAX. *Electric Railway Journal*, v. 35, p. 274 (Feb. 12, 1910). (Very brief statement.)

Middlesex & Boston Street Ry.

LIABILITIES ON WHICH PROPER RETURNS SHOULD BE ALLOWED. *Electric Railway Journal*, v. 34, p. 464 (Sept. 25, 1909). (Hearing before Massachusetts Board of Railroad Commissioners; discussion of the basis on which the value of the property of the Middlesex & Boston Street Ry. should be computed.)

Milwaukee Electric Ry. & Light Co.

*DECISION IN THE MILWAUKEE FARE CASE. *Electric Railway Journal*, v. 40, p. 314 (Aug. 31, 1912). (Gives summary of physical valuation, going value, treatment of allowance for depreciation, rate of return, etc., of Milwaukee Light, Heat & Traction Co. and Milwaukee Electric Ry. & Light Co.)

DEPRECIATION AND RESERVE FUNDS IN MILWAUKEE. (Editorial.) *Street Railway Journal*, v. 26, p. 441 (Sept. 23, 1905). (Gives actual figures.)

DEPRECIATION OF PUBLIC UTILITIES PROPERTIES. *Electric Railway Journal*, v. 31, p. 169 (Feb. 1, 1908). (On the subject of depreciation in general, with reference to Milwaukee street railways.)

——Editorial. Depreciation. *Electric Railway Journal*, v. 31, p. 104 (Jan. 25, 1908).

DEPRECIATION RESERVES OF THE MILWAUKEE AND ST. LOUIS RAILWAYS. *Electric Railway Review*, v. 17, p. 319 (March 9, 1907). (Comparison of totals of maintenance and depreciation charges for fiscal year 1906, for street railways in Milwaukee, St. Louis, Chicago, and Glasgow.)

A DISCUSSION OF THE MILWAUKEE FARE DECISION. *Electric Railway Journal*, v. 41, p. 110 (Jan. 18, 1913). (Discusses valuation of Milwaukee street railway.)

THE ELECTRIC RAILWAY SYSTEM OF MILWAUKEE AND EASTERN WISCONSIN. *Street Railway Journal*, v. 15, p. 352 (June, 1899). (Provision of the Milwaukee Electric Ry. & Light Co., for depreciation and other reserves.)

——Editorial. *Street Railway Journal*, v. 15, p. 369 (June, 1899).

*HEARINGS ON MILWAUKEE FARE CASE BY WISCONSIN RAILROAD COMmission. *Electric Railway Journal*, v. 32, p. 395; v. 33, pp. 419, 464, 499, 554, 640, 683, 729, 766, 955 (Aug. 1, 1908; March 6, 13, 20, 27; April 3, 10, 17, 24; May 22, 1909). (Testimony by many experts on the value of the Milwaukee Electric Ry. & Light Co.'s property, allowances for depreciation, etc.)

——Editorial. *Electric Railway Journal*, v. 33, pp. 452, 536 (March 13, 27, 1909).

THE MILWAUKEE FOUR-CENT FARE DECISION. *Street Railway Journal*, v. 14, p. 397 (July, 1898). (Opinions of William H. Seaman, United States District Judge, in the case of the Milwaukee Electric Ry. & Light Co.; three pages.)

——Editorial. *Street Railway Journal*, v. 14, p. 381 (July, 1898).

STREET AND INTERURBAN RAILROADS—SPECIAL CASES—(*Continued*).

VALUATION OF MILWAUKEE PROPERTIES. *Electric Railway Journal*, v. 38, p. 160 (July 22, 1911). (Details of the values placed on the property of the Milwaukee Electric Ry. & Light Co. by the Railroad Commission of Wisconsin; very brief.)

——Editorial. *Electric Railway Journal*, v. 38, p. 143 (July 22, 1911).

Milwaukee Northern Ry. Co.

*EDWARD J. CHROMASTER VS. MILWAUKEE NORTHERN RAILWAY COMPANY; Submitted May 15, 1911, Decided March 12, 1912. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 8, p. 734. Madison, Wis., 1912. (Table of total valuation of property of Milwaukee Northern Ry. Co. and apportionment between city and interurban.)

Nebraska.

*PROPOSED DEPRECIATION ACCOUNT IN NEBRASKA. *Electric Railway Journal*, v. 37, p. 919 (May 27, 1911). (Brief reference to hearing before the State Railway Commission on proposed depreciation account for electric railways.)

*RULE FOR TREATMENT OF DEPRECIATION IN NEBRASKA. *Electric Railway Journal*, v. 38, p. 990 (Nov. 4, 1911). (Rules adopted by State Railway Commission to govern charges by electric railways, for maintenance, additions and betterments; one-half page.)

New Jersey.

REQUEST FOR LOWER FARES DENIED BY NEW JERSEY COMMISSION. *Electric Railway Journal*, v. 38, p. 1117 (Nov. 25, 1911). (Contains brief reference to the value of street railway property and allowance for maintenance and depreciation.)

STANDARD CLASSIFICATION OF STREET RAILWAY ACCOUNTS IN NEW JERSEY. *Electric Railway Review*, v. 37, p. 273 (Feb. 11, 1911). (The adoption, with two slight changes, of the standards of the American Electric Railway Accountants Association in regard to depreciation.)

New York City.

ANOTHER THIRD AVENUE CHAPTER. (Editorial.) *Electric Railway Journal*, v. 39, p. 230 (Feb. 10, 1912). (The Commission provides a plan for the retirement of excessive capitalization of the property; very brief.)

*APPRAISAL OF THE NEW YORK SURFACE SYSTEMS. (Editorial.) *Electric Railway Journal*, v. 32, p. 111 (June 20, 1908). (Discussion of the proposed appraisal by the Public Service Commission; one page.)

THE APPRAISAL OF THE THIRD AVENUE STREET RAILROAD SYSTEM, NEW York City. *Engineering and Contracting*, v. 35, p. 666 (June 7, 1911). (Data relating to the appraisal taken from a pamphlet entitled "Opinion Disapproving Plan of Reorganization," July 29, 1910.)

AN ARBITRARY DEPRECIATION REQUIREMENT. (Editorial.) *Railway World*, v. 56, p. 141 (Feb. 16, 1912). (On decision of the New York Public Service Commission on the Third Avenue Ry.)

*LIFE OF ELEMENTS OF SUBWAY PROPERTY. *Electric Railway Journal*, v. 39, p. 575 (April 6, 1912). (Estimates of E. G. Connette, Transportation Engineer, New York Public Service Commission, First District.)

METROPOLITAN STREET RAILWAY REORGANIZATION. *Electric Railway Journal*, v. 37, pp. 708, 756, 798, 876, 916, 976; v. 38, p. 240 (April 22, 29, May 6, 20, 27, June 3, Aug. 5, 1911). (Hearing before the New York Public Service Commission, First District; testimony in relation to the value of the property.)

*OPINIONS OF COMMISSION IN THIRD AVENUE CASE. *Electric Railway Journal*, v. 39, p. 237 (Feb. 10, 1912). (Opinions on mortgages and accounting, amortization of discounts and depreciation of the Third Avenue R. R. property.)

PHYSICAL APPRAISAL OF THIRD AVENUE RAILROAD. *Electric Railway Journal*, v. 35, p. 228 (Feb. 5, 1910). (Estimate by Henry Floy of the value of the Third Avenue R. R.; one-half page.)

PLAN FOR REORGANIZATION OF THIRD AVENUE ROAD DISAPPROVED BY Commission. *Electric Railway Journal*, v. 36, p. 262 (Aug. 13, 1910). (Contains statement regarding the value of the property; three pages.)

*RE AMORTIZATION ACCOUNTS OF THE THIRD AVENUE RAILWAY COMPANY (Case 1181). Reports of Decisions of the Public Service Commission, First District of the State of New York, v. 3, p. 51. New York, 1912. (Amortization of discounts and depreciation.)

*RE BOND ISSUE OF NEW YORK & NORTH SHORE TRACTION COMPANY (CASE 1398). Reports of Decisions of the Public Service Commission, First District of the State of New York, v. 3, p. 63. New York, 1912. (Discussion of valuation of property of the New York & North Shore Traction Co.)

STREET AND INTERURBAN RAILROADS—SPECIAL CASES—(*Continued*).

*RE METROPOLITAN STREET RAILWAY COMPANY REORGANIZATION (CASE 1305). Reports of Decisions of the Public Service Commission, First District of the State of New York, v. 3, p. 113. New York, 1912. (Estimates of valuation of property.)

*RE 2ND REORGANIZATION PLAN OF 3RD AVE. R. R. CO. (CASE 1181). Reports of Decisions of the Public Service Commission, First District of the State of New York, v. 2, p. 390. New York, 1912. (Report on valuation of the property of the Third Avenue R. R. Co.)

*REPORT OF A COMMITTEE OF THE BOARD OF ESTIMATE AND APPORTIONment and of the Public Service Commission for the First District with Relation to Pending Proposals for Rapid Transit Lines (1911). Proceedings, Public Service Commission for the First District, State of New York, v. 6, pp. 378, 399, 488 (June 27, 30, July 21, 1911). New York, 1912. (Estimated value of proposed New York Subway.)

*THE RETURN ON THE INVESTMENT IN THE SUBWAY OF THE INTERBOROUGH Rapid Transit Company of New York City, Submitted to the Public Service Commission for the First District of the State of New York, Report No. 7, Dec. 31, 1908; by Bion J. Arnold. New York, 1908. (Analysis of earnings and expenses, depreciation, etc.)

*SECOND CONDENSATION OF OPERATING ACCOUNTS FOR NEW YORK ROADS. *Electric Railway Journal,* v. 33, p. 67 (Jan. 9, 1909). (Classification of accounts made by New York Public Service Commission, First District; includes depreciation and treatment of appreciation.)

TENTATIVE CLASSIFICATION OF ACCOUNTS PREPARED BY NEW YORK PUBLIC Service Commission. *Electric Railway Journal,* v. 32, p. 349 (July 25, 1908). (The classification provides for two accounts to cover depreciation, one under maintenance of way and structures and one under maintenance of equipment.)

TREATMENT OF DEPRECIATION ACCOUNTS BY INTERBOROUGH RAPID TRANSIT Co. *Electric Railway Journal,* v. 38, p. 280 (Aug. 12, 1911). (One page.)

*TREATMENT OF DEPRECIATION AND MAINTENANCE IN GREATER NEW YORK. *Electric Railway Journal,* v. 39, p. 539 (April 6, 1912). (Table of rates of depreciation adopted by street and electric railway companies in accordance with the uniform system of accounts prescribed by the Public Service Commission of the First District.)

VALUATION OF STREET RAILWAY PROPERTIES. *Electric Railway Journal,* v. 33, p. 1122 (June 19, 1909). (Relates more particularly to the street railways of New York City; two and one-half pages.)

New York State.

*ACCOUNTS PRESCRIBED BY NEW YORK PUBLIC SERVICE COMMISSION, Second District. *Electric Railway Journal,* v. 32, p. 1373 (Nov. 14, 1908). (Provision is made for the treatment of depreciation in two primary operating expense accounts.)

BRIEF ON ACCOUNTING SCHEME SUBMITTED TO PUBLIC SERVICE COMMISSION, Second District, on Behalf of New York State Association. *Electric Railway Review,* v. 19, p. 591 (May 16, 1908). (Protest against requiring same methods of accounting for steam and electric railways and reasons for the protest).

INQUIRY BY PUBLIC SERVICE COMMISSION CONCERNING DEPRECIATION Accounts. *Electric Railway Journal,* v. 35, p. 793 (April 30, 1910). (Circular letter of inquiry issued to street railroad and electrical corporations, by the New York Public Service Commission, Second District; very brief.)

*JOINT HEARING ON UNIFORM ACCOUNTS FOR NEW YORK ELECTRIC ROADS. *Electric Railway Journal,* v. 32, p. 439 (Aug. 8, 1908). (Statement of H. J. Pierce, President of the International Ry. Co. of Buffalo, on depreciation, and of Howard Abel, Comptroller of the Brooklyn Rapid Transit System, on classification of accounts.)

RESOLUTIONS OF NEW YORK STATE ASSOCIATION CONCERNING TENTATIVE Classifications. *Electric Railway Review,* v. 19, p. 378 (March 28, 1908). (Relates to classification of the New York Public Service Commission, Second District.)

*SECOND CONDENSATION OF OPERATING EXPENSE ACCOUNTS FOR NEW YORK Roads. *Electric Railway Journal,* v. 33, p. 67 (Jan. 9, 1909). (Scheme of accounts prescribed by New York Public Service Commission, Second District, for street railroads; three paragraphs relating to depreciation.)

*STATE OF NEW YORK, SECOND ANNUAL REPORT OF THE PUBLIC SERVICE Commission, Second District, for the Year Ending Dec. 31, 1908; v. 2, Uniform System of Accounts. Albany, 1909. (Classification of accounts for street railroads, gas and electrical corporations; general amortization account including amount estimated for wear, tear and obsolescence of plant.)

STREET AND INTERURBAN RAILROADS—SPECIAL CASES—(*Continued*).

*VALUATION BY EARNINGS; by Frank W. Stevens. *Public Service Regulation,* v. 1, p. 438 (July, 1912). (Opinion of Chairman, New York Public Service Commission, Second District, in the application of the Westchester Street R. R. Co. for authorization to issue capital stock.)

VALUE OF PROPERTY IN NEW YORK REORGANIZATION CASE. *Electric Railway Journal,* v. 41, p. 381 (March 1, 1913). (Decision of the New York Public Service Commission, Second District, in the case in which the Westchester Street R. R. asked authority to issue capital stock.)

Newcastle, England.

DEPRECIATION AND RESERVES, WARNING TO NEWCASTLE. *Tramway and Railway World,* v. 20, p. 258 (Sept. 6, 1906). (Discussion on the necessity of reserve and renewal funds; statistical.)

Niagara Gorge R. R.

TREATMENT OF DEPRECIATION ACCOUNTS OF NEW YORK PUBLIC SERVICE Commission. *Electric Railway Journal,* v. 34, p. 1073 (Nov. 20, 1909). (Rules adopted by the Niagara Gorge R. R.)

Philadelphia, Pa.

*PENNSYLVANIA STATE RAILROAD COMMISSION IN THE MATTER OF THE Complaints Against the Philadelphia Rapid Transit Company; Report to the Commission by Ford, Bacon & Davis, March 7, 1911. 2 v. New York, 1911. (Detailed report, comprising a series of tabulated statements, maps and diagrams on the physical valuation of the property of the Philadelphia Rapid Transit Co.)

Puget Sound Electric Ry.

*FIFTH ANNUAL REPORT OF THE RAILROAD COMMISSIONER OF WASHINGTON to the Governor Covering the Period from January 1 to November 1, 1910, p. 49. Olympia, Wash., 1910. (Refers to valuation of the Puget Sound Electric Ry.)

VALUATION OF THE PUGET SOUND ELECTRIC RAILWAY; by Henry L. Gray. *Engineering-Contracting,* v. 33, p. 482 (May 25, 1910). (Methods and details of valuation of physical property; four pages.)

St. Louis, Mo.

DEPRECIATION FUND IN ST. LOUIS. (Editorial.) *Electric Railway Journal,* v. 35, p. 433 (March 12, 1910). (One paragraph.)

LARGER DEPRECIATION FUND FOR ST. LOUIS. (Editorial.) *Electric Railway Journal,* v. 37, p. 247 (Feb. 11, 1907). (Comments on the policy of the United Railways Co. of St. Louis.)

*REPORT TO THE MUNICIPAL ASSEMBLY ON THE UNITED RAILWAYS COMpany of St. Louis by the St. Louis Public Service Commission; by James E. Allison. 2 v. Woodward & Tiernan Printing Co., St. Louis, 1912. (A statement of the principles which in the opinion of the Commission should be the basis of valuation and details of physical valuation of the property; Appendix A contains a discussion by James E. Allison, "Should Public Service Properties be Depreciated to Obtain Fair Value in Rate or Regulation Cases?")

——Abstracts. Report on United Railways of St. Louis. *Electric Railway Journal,* v. 41, p. 248 (Feb. 8, 1913); Finding Fair Value. *Public Service Regulation,* v. 1, p. 716 (Nov., 1912).

San Francisco, Cal.

FINAL REPORT ON SAN FRANCISCO. *Electric Railway Journal,* v. 41, p. 844 (May 10, 1913). (Analysis of value of street railways of San Francisco; report by Bion J. Arnold.)

Savannah, Ga.

DECISION OF COMMISSION UPHOLDING RATES OF FARE IN SAVANAH, GA. *Electric Railway Journal,* v. 39, p. 663 (April 20, 1912). (Relates to value of street railway property.)

Sheboygan, Wis.

*CITY OF SHEBOYGAN VS. SHEBOYGAN RAILWAY AND ELECTRIC COMPANY; Submitted Oct. 18, 1910, Decided Feb. 3, 1911. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 6, p. 358. Madison, Wis., 1912. (Contains table of valuation of the physical property of the Sheboygan Ry. & Electric Co.)

Spokane & Inland Empire R. R. System.

APPRAISAL OF THE SPOKANE AND INLAND EMPIRE ELECTRIC RAILROAD System; by Henry L. Gray. *Engineering and Contracting,* v. 36, p. 696 (Dec. 27, 1911). (Contains tables of cost of reproduction, depreciation, etc.; deals with methods adopted to determine the correctness of the allegation concerning the insufficiency of present rates.)

STREET AND INTERURBAN RAILROADS—SPECIAL CASES—(*Continued*).

Sunderland, England.

DEPRECIATION AT SUNDERLAND. *Tramway and Railway World*, v. 14, p. 478 (Nov. 12, 1903). (Estimated life and percentage set aside for depreciation of equipment and permanent way of street railway at Sunderland, England.)

Toledo, Ohio.

INVENTORY OF PHYSICAL RAILWAY PROPERTY OF TOLEDO COMPANY GIVEN to City. *Electric Railway Journal*, v. 36, p. 990 (Nov. 12, 1910). (Letter from Ford, Bacon & Davis; gives a list of the work and expense items entering into the construction cost which should be included in an appraisal; one page.)

Wausau, Wis.

*DECISION OF WISCONSIN COMMISSION: CONSIDERS THE RATE OF RETURN. *Electric Railway Journal*, v. 36, p. 404 (Sept. 10, 1910). (Statement in regard to the valuation of the Wausau Street R. R. Co.; one page.)

Wisconsin.

SOME PRINCIPLES ESTABLISHED BY THE WISCONSIN RAILROAD COMMISSION; by Edwin S. Mack. *Electric Railway Journal*, v. 37, p. 164 (Jan. 28, 1911). (Includes valuation; one page.)

*SYSTEM OF ACCOUNTS PRESCRIBED BY WISCONSIN RAILROAD COMMISSION. *Electric Railway Journal*, v. 33, p. 1076 (June 12, 1909). (Includes provision for a depreciation fund; two pages.)

*WISCONSIN CLASSIFICATION OF ACCOUNTS. *Electric Railway Journal*, v. 34, p. 366 (Sept. 4, 1909). (Gives slight changes from list published June 12, 1909, with extracts from introductory letter of the Commission.)

STREET AND INTERURBAN RAILROADS—UNVERIFIED REFERENCES.

ACCOUNTING OF DEPRECIATION BY ELECTRIC RAILWAYS; by Robert N. Wallis. *Journal of Accountancy*, May, 1907. (Discusses methods used and matters to be considered in electric railway accounting.)

ALLOWANCE FOR MAINTENANCE TO COVER DEPRECIATION. *Light Railway and Tramway Journal* (London), v. 21, p. 29 (July 2, 1909). (Details of allowances as agreed between Council of Institute of Municipal Treasurers and Accountants and the Inland Revenue Department for tramway and light railways as well as for municipal corporations.)

CLASSIFICATION OF ELECTRIC RAILWAY EXPENSES; by Willard Hubbard Lawton. *Journal of Accountancy*, v. 6, p. 114 (June, 1908).

COST OF CARRYING A PASSENGER; by C. L. S. Tingley. *Street Railway Bulletin*, v. 4, p. 793 (Nov. 15, 1905). (Abstract.)

DEPRECIATION AND RENEWAL FUNDS IN RELATION TO TRAMWAYS UNDERtakings; by G. W. Holford. *Light Railway and Tramway Journal* (London), v. 15, p. 294 (Oct. 5, 1906). (Abstract of paper read before the Municipal Tramways Association; contains table showing provision made for depreciation by street railways in sixty English cities.)

DEPRECIATION OF TRAMWAYS AND LIGHT RAILWAYS. *Light Railway and Tramway Journal* (London), v. 21, p. 80 (Aug. 6, 1909).

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STREET AND INTERURBAN RAILROADS–UNVERIFIED REFERENCES–(*Continued*).

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VALUATION OF CLEVELAND RAILWAY CO.: LETTER OF DEC. 17, 1909, TO CITY Council of Cleveland, Ohio, by R. W. Taylor, as Arbitrator Between City and Railways. (Copy in files, American Electric Railway Association.)

VALUATION OF PROPERTY OF RAILROADS IN THE DISTRICT OF COLUMBIA. 62d Cong., 2d Sess. Senate Doc. No. 335. (Letter in response to Senate resolution of Feb. 14th, 1912.)

TELEGRAPH AND TELEPHONE.

AN ANALYSIS OF COST OF TELEPHONE SERVICE. *Electrical World*, v. 55, p. 1243 (May 19, 1910). (One page.)

DEPRECIATION AND REPLACEMENT OF GROWING TELEPHONE PLANTS; by Burke Smith. *Journal*, Western Society of Engineers, v. 17, p. 779 (Oct., 1912). (Discusses renewal, life and depreciation of plant.)

——Abstract. Depreciation and Replacement of Telephone Equipment. *Electrical Review and Western Electrician*, v. 60, p. 790 (April 27, 1912). (Very brief.)

THE DEPRECIATION OF UNDERGROUND CABLES; by F. Fernie. *Electrical Review* (London), v. 60, p. 577 (April 5, 1907). (Method of computing depreciation of cables.)

DEPRECIATION OF UNDERGROUND CONDUITS, CABLES AND WIRES. *Electric Railway Journal*, v. 33, p. 881 (May 8, 1909). (Classification of property of the American Telephone & Telegraph Co.; very brief.)

DETERMINATION OF TELEPHONE RATES FOR LARGE EXCHANGES; by William H. Crumb. *Journal*, Western Society of Engineers, v. 12, p. 781 (Dec., 1907). (On depreciation, with a table giving per cent. to be allowed to depreciation account; one-half page.)

PLANT-INVENTORY AND VALUATION. *Electrical World*, v. 55, p. 295 (Feb. 3, 1910). (Abstract of paper by W. R. McGovern before the Wisconsin Electrical Association covering in a general way methods of taking inventories of telephone-exchange plants in Wisconsin.

——Abstract and Discussion. *Electric Railway Journal*, v. 35, p. 184 (Jan. 29, 1910).

TELEPHONE CONSTRUCTION METHODS AND COST. Chicago, 1908. (Contains cost data from the actual records of various telephone companies.)

***UNIFORM SYSTEM OF ACCOUNTS FOR TELEPHONE COMPANIES AS PRE**scribed by the Interstate Commerce Commission, pp. 16, 34, 53, 66, 71, 77. Washington, 1912. (Refers to treatment of depreciation.)

TELEGRAPH AND TELEPHONE–SPECIAL CASES.

Augusta, Wis.

***IN RE APPLICATION OF J. L. BALL FOR AUTHORITY TO INCREASE TELE**phone Rates; Submitted Sept. 10, 1907, Decided Nov. 25, 1907. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 2, p. 105. Madison, Wis., 1909. (Brief reference to physical valuation.)

Boston, Mass.

REPORT TO THE MASSACHUSETTS HIGHWAY COMMISSION ON TELEPHONE Rates for Boston and Suburban District; by D. C. and William B. Jackson. Boston, 1910. (Diagrams, tables and maps; sixty-six pages.)

Chicago, Ill.

THE APPRAISAL OF THE CHICAGO TELEPHONE CO. AND A COMPARISON WITH the Results of Three Similar Appraisals. (Editorial.) *Engineering and Contracting*, v. 36, p. 269 (Sept. 13, 1911). (One column.)

APPRAISAL OF THE CHICAGO TELEPHONE COMPANY AND DETERMINATION of Fair Rates of Charge; by William J. Hagenah. *Engineering-Contracting*, v. 36, pp. 289, 445, 473 (Sept. 13, Oct. 25, Nov. 1, 1911). (Method of arriving at plant value, appraised value and income and operating expenses.)

REPORT ON THE TELEPHONE SITUATION IN THE CITY OF CHIGAGO IN RESPECT to Service, Rates, Regulation of Rates, etc., Submitted to the Committee on Gas, Oil and Electric Light of the City Council of the City of Chicago; by a Special Committee, composed of Dugald C. Jackson, William H. Crum, and George W. Wilder, April, 1907. Chicago, 1907. (The Committee states that it has endeavored to obtain data from Bell Telephone Companies of New York and elsewhere, but rates seem to have been dictated by estimates based on experience or the requirements of business expediency.)

TELEGRAPH AND TELEPHONE—SPECIAL CASES—(*Continued*).

Clinton Telephone Co.

*B. B. TIGHE ET AL. VS. CLINTON TELEPHONE COMPANY; Submitted Oct. 10, 1908, Decided Dec. 2, 1908. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 3, p. 117. Madison, Wis., 1910. (Refers to tentative valuation of physical property.)

Massachusetts.

SIXTEENTH ANNUAL REPORT OF THE MASSACHUSETTS HIGHWAY COMMISSion, for the Fiscal Year ending Nov. 30, 1908, p. 158. Boston, 1909. (Contains report by Dugald C. Jackson on the advisability of making an appraisal of the New England Telephone & Telegraph Co.)

——17th, p. 211. Boston, 1910. (Contains a summary report of the results of the inventory and appraisal of the New England Telephone & Telegraph Co., by D. C. and W. B. Jackson.)

TELEPHONE REPORT TO MASSACHUSETTS HIGHWAY COMMISSION. *Electrical World*, v. 55, p. 984 (April 21, 1910). (Brief reference to report on the New England Telephone & Telegraph Co., by D. C. and W. B. Jackson; states that this report on traffic and operating conditions, together with the appraisal which appeared previously, is the most detailed analysis ever made of telephone rates in an urban area of such scope.)

Michigan.

THE VALUATION AND TAXATION OF TELEPHONE COMPANIES IN MICHIGAN; by W. J. Rice. *Electrical World*, v. 37, p. 196 (Feb. 2, 1901). (Two and one-half pages.)

Portage, Wis.

*IN RE APPLICATION OF THE PORTAGE TELEPHONE COMPANY FOR AUTHORity to Increase Rates; Submitted May 19, 1908, Decided Aug. 27, 1908. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 2, p. 692. Madison, Wis., 1909. (Contains brief data on valuation.)

Seattle, Wash.

APPRAISAL OF THE PACIFIC TELEPHONE AND TELEGRAPH COMPANY OF Seattle; by Henry L. Gray. *Engineering and Contracting*, v. 36, p. 332 (Sept. 27, 1911). (Gives detailed estimate of cost of reproducing the plant; five pages.)

APPRAISAL OF THE SEATTLE TELEPHONE COMPANIES BY THE RAILROAD Commission of Washington; by Henry L. Gray. *Engineering and Contracting*, v. 35, p. 520 (May 3, 1911). (Describes the work and explains the causes which led to the appraisal.)

STUDY OF THE TELEPHONE SITUATION IN SEATTLE, WASH.: REPORT; by C. H. Judson and F. B. Hall. *Engineering News*, v. 65, p. 652 (June 1, 1911). (On depreciation and valuation; one column.)

Wisconsin Telephone Co.

*E. E. PAYNE ET AL. VS. WISCONSIN TELEPHONE COMPANY; Decided Aug. 3, 1909. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 4, p. 1. Madison, Wis., 1910. (Intangible values embracing franchise, good will and going value are briefly discussed.)

TELEGRAPH AND TELEPHONE—UNVERIFIED REFERENCES.

DEPRECIATION AND REPLACEMENT OF GROWING TELEPHONE PLANTS; by Burke Smith. *Telephony*, April 27, 1912, p. 1062.

NATIONAL TELEPHONE CO., LIMITED, VS. HIS MAJESTY'S POSTMASTER-General. Great Britain Railway and Canal Commission Court. Judgment, Jan. 13, 1913, pp. 4209-39.

REPORT OF THE INVESTIGATION OF THE CHICAGO TELEPHONE COMPANY, 1911; by William J. Hagenah.

REPORT OF UNFAIR TELEPHONE RATES IN MINNEAPOLIS, TAKES UP ALLOWance for Depreciation; by Gordon Steele & Co. *Public Service*, v. 5, p. 106 (Oct., 1908).

TELEPHONE VALUATION, OKLAHOMA. Pioneer Telephone & Telegraph Co. *vs.* E. S. Westenhaver *et al.* and State of Oklahoma. Oklahoma Supreme Court, 1910, p. 1256.

WATER POWER—GENERAL.

AN ANALYSIS OF THE "COMMERCIAL" VALUE OF WATER-POWER PER Horse-power per Annum; by A. F. Nagle. *Transactions*, American Society of Mechanical Engineers, v. 24, p. 286 (1903). (With discussion.)

——Abstract. *Engineering News*, v. 49, p. 83 (Jan. 22, 1903).

WATER POWER—GENERAL—(*Continued*).

THE APPRAISAL OF WATER POWER RIGHTS; by Halbert P. Gillette. *Engineering and Contracting*, v. 38, p. 624 (Dec. 4, 1912). (Discusses seven methods of appraisal: the steam comparison method; the capitalized profit method; the alternative use method; the next available water power method; the public utility factor method; the market value method; and capitalized rental method.)

COMMENTS ON DEVELOPMENT AND OPERATION OF HYDRO-ELECTRIC PLANTS; by Henry L. Doherty. *Proceedings*, American Institute of Electrical Engineers, v. 28, Pt. 2, p. 1362 (1909). (Treat of value of water-power securities, cost of power and depreciation.)

——Abstract. Cost and Depreciation of Steam and Hydro-Electric Installations. *Electrical World*, v. 54, p. 1558 (Dec. 30, 1909).

COMPARATIVE COST OF STEAM AND WATER POWER; by Charles H. Manning. *Transactions*, American Society of Mechanical Engineers, v. 10, p. 499 (1889). (On the value of water power.)

THE COMPARATIVE VALUES OF WATER-POWER AND STEAM POWER; by A. C. Dunham. *Electrical World*, v. 59, p. 38 (Jan. 6, 1912). (Advantages and disadvantages of hydro-electric stations for central-station service compared with steam-driven stations, financial considerations involved.)

——Abstract. The Value of Water Power. *Engineering Record*, v. 65, p. 181 (Feb. 17, 1912).

COMPUTATION OF THE VALUE OF WATER POWERS AND THE DAMAGES Caused by the Diversion of Water Used for Power; by Charles T. Main. *Journal*, New England Water Works Association, v. 21, p. 214 (Sept., 1907). (Contains a table of estimated costs per horse-power of water-power plants.)

——Abstracts. *Engineering-Contracting*, v. 29, p. 73 (Jan. 29, 1908); *Journal of Electricity, Power and Gas*, v. 22, p. 20 (June 30, 1909).

COMPUTATION OF THE VALUES OF WATER POWERS AND THE DAMAGES Caused by the Diversion of Water Used for Power; by Charles T. Main. *Transactions*, American Society of Mechanical Engineers, v. 26, p. 68 (1905). (Gives definitions of value and damage and method of determining value.)

COST OF GENERATING ELECTRIC POWER; by F. A. Griffin. *Street Railway Journal*, v. 26, p. 1142 (Dec. 30, 1905). (Gives diagram of maintenance of generating station and states that the cost of generating power by water can be found from the diagram by eliminating the cost of coal.)

COST OF STEAM AND WATER POWER; by Charles T. Main. *Transactions*, American Society of Mechanical Engineers, v. 11, p. 108 (1889). (On value of water power.)

THE COST OF STEAM POWER; by Charles E. Emery. *Transactions*, American Society of Civil Engineers, v. 12, p. 425 (Paper 266. Nov., 1883). (In a suit respecting the loss of power by the diversion of water, damages were claimed by mill owners based on the cost of purchasing, operating and maintaining at each mill a small engine and a complete independent steam plant.)

DAMAGES CAUSED BY THE DIVERSION OF WATER-POWER; by Clemens Herschel. *Journal*, New England Water Works Association, v. 21, p. 241 (Sept., 1907). (On methods of estimating market value of water power.)

ELECTRIC POWER TRANSMISSION; by Frederick Darlington. *Transactions*, American Institute of Electrical Engineers, v. 25, p. 181 (1906). (Cost of developing and maintaining hydro-electric power utilized in mill work, in comparison with steam power.)

ELECTRIC TRANSMISSION OF WATER-POWER, p. 1; by Alton D. Adams. McGraw Publishing Co., New York, 1906. (On water-power and its utility in electrical supply, relates to the cost of water power; two chapters.)

EVALUATION OF WATER RIGHTS; by Arthur Halsted. *Engineering Record*, v. 61, p. 245 (Feb. 26, 1910). (On methods of valuation; two pages.)

HYDRAULIC DEVELOPMENTS AS RELATED TO ELECTRIC INSTALLATIONS; by William B. Jackson. *Journal*, Western Society of Engineers, v. 8, p. 312 (June, 1903). (Contains a discussion by T. T. Johnson on the economic side of a water-driven electric plant.)

HYDRO-ELECTRIC POWER VERSUS STEAM FOR INDUSTRIAL PURPOSES; by H. von Schon. *Engineering Magazine*, v. 33, pp. 34, 184, 353 (April, May, June, 1907). (A comparison of costs of hydro-electric and steam power in developed and undeveloped plants.)

A METHOD OF ESTIMATING THE LOSS OF WATER POWER IN A STREAM BY Taking Water Therefrom for a City Supply; by L. M. Hastings. *Journal*, New England Water Works Association, v. 7, p. 187 (June, 1893). (Discussion on the value of the water power.)

——Abstract. *Engineering Record* v. 27, p. 296 (March 11, 1893).

WATER POWER—GENERAL—(*Continued*).

NOTES ON DESIGN OF HYDRO-ELECTRIC POWER STATIONS, WITH REFERENCE to the Influence of Load-Factor; by David B. Rushmore. *Transactions*, American Institute of Electrical Engineers, v. 25, p. 145 (1906). (The discussion of costs is confined to general principles; definite values are not given.)

ON THE VALUE OF A HORSE-POWER; by George I. Rockwood. *Transactions*, American Society of Mechanical Engineers, v. 21, p. 590 (1900). (On the dispute between the city officials of Worcester and the mill owners on the loss of power by the diversion of water for the Worcester Reservoirs.)

THE RELATION OF LOAD-FACTOR TO THE EVALUATION OF HYDRO-ELECTRIC Plants; by S. B. Storer. *Transactions*, American Institute of Electrical Engineers, v. 25, p. 139 (1906). (Contains diagrams giving comparative cost of steam and hydro-electric plants.)

RELATION OF STEAM TO WATER POWER; by James G. Hill. *Transactions*, New England Cotton Manufacturers' Association, v. 65, p. 333 (1898). (Contains a table giving yearly cost of 1 h.p. of water.)

THE SALE AND MEASUREMENT OF ELECTRIC POWER; by S. B. Storer. *Street Railway Journal*, v. 27, p. 1018 (June 30, 1906). (Contains diagrams giving methods of plotting costs and prices per horse-power per year of steam or hydro-electric power.)

STORAGE AND PONDAGE OF WATER; by Joseph P. Frizell. *Transactions*, American Society of Civil Engineers, v. 31, pp. 29, 552 (Papers 688 and 709. Jan., May, 1894). (On the valuation of water power.)

VALUATION OF MANUFACTURING PROPERTY FOR TAXATION; by Charles T. Main. *Transactions*, New England Cotton Manufacturers Association, v. 67, p. 108 (1899). (Contains data on the method of determining the value of water power.)

THE VALUATION OF WATER POWER AND THE ESTIMATION OF STREAM Diversion Damages; by Robert E. Horton. *Proceedings*, American Water Works Association, v. 29, p. 1 (1909). (Twenty-five pages.)

THE VALUE AND DESIGN OF WATER POWER PLANTS AS INFLUENCED BY Load-Factor; by Frederick A. C. Perrine. *Journal*, Franklin Institute, v. 162, p. 269 (Oct., 1906).

THE VALUE OF A WATER POWER; by Charles T. Main. *Transactions*, American Society of Mechanical Engineers, v. 13, p. 140 (1891). (On method of estimating the value of water power with relation to condemnation proceedings.)

THE VALUE OF WATER; by Alton D. Adams. *Municipal Engineer*, v. 37, p. 77 (Aug., 1909). (Decision of the Massachusetts Court as to the general rule of compensation where water is taken under legislative authority for public use.)

——Editorial. Value of Water and Water Power. *Municipal Engineering*, v. 37, p. 102 (Aug., 1909).

THE VALUE OF WATER POWER. (Editorial.) *Engineering Record*, v. 33, p. 597 (May 9, 1896). (Dealing with the general and special conditions and circumstances that should be considered in the condemnation of water supplies for municipal purposes; two columns.)

WATER POWER. In Geological Survey of New Jersey, Final Report, v. 3, Henry B. Kummel, State Geologist. Trenton, N. J., 1894. (Data on the cost of water power.)

WATER RIGHTS; by Richard A. Hale. *Journal*, New England Water Works Association, v. 21, p. 248 (Sept., 1907). (The discussion of this paper relates to the valuation of water power.)

WATER POWER—SPECIAL CASES.

Beloit, Wis.

***CITY OF BELOIT VS. BELOIT WATER, GAS AND ELECTRIC COMPANY**; Decided July 19, 1911. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 7, p. 246. Madison, Wis., 1912. (Gives estimates of value of the water power.)

***VALUATION OF WATER POWER.** *Engineering Record*, v. 61, p. 153 (Feb. 5, 1910). (Case of the Beloit Water, Gas & Electric Co. before the Wisconsin Railroad Commission; abstracts of testimony.)

Boston, Mass.

BOSTON BELTING COMPANY VS. CITY OF BOSTON. Boston, 1899. (Suit relates to the diversion of water from Stony Brook and the value of the water power; fifty-nine parts.)

WATER POWER—SPECIAL CASES—(*Continued*).

Bronx River.

CALCULATIONS OF THE MEAN HORSE-POWER OF A VARIABLE STREAM AND the Cost of Replacing the Power Lost by a Partial Diversion of the Flow; by William H. Grant. *Transactions,* American Society of Civil Engineers, v. 22, p. 389 (Paper 440. June, 1890). (In regard to the claims of property owners for diversion of part of the waters of the Bronx River.)

Connecticut River Transmission Co.

HEARING ON CONNECTICUT RIVER TRANSMISSION COMPANY'S FRANCHISE. *Electrical World,* v. 53, p. 486 (Feb. 25, 1909). (Brief data on the estimated value of the plant.)

Everett (Wash.) Ry., Light & Power Co.

*THE APPRAISAL OF WATER RIGHTS. *Engineering and Contracting,* v. 37, p. 429 (April 17, 1912). (Report made by Halbert P. Gillette to the Everett Ry., Light & Water Co. as part of the Company's exhibits in a recent hearing before the Washington Public Service Commission.)

Holyoke, Mass.

HOLYOKE WATER POWER CO. VS. CITY OF HOLYOKE. 20 v. George H. Ellis, Boston, 1899. (Suit in regard to the value of the water power.)

Illinois.

REPORT ON THE WATER POWER OF THE ROCK RIVER AT STERLING AND Rock Falls, Illinois, and the Probable Effect on the Power of the Diversion of Water for Feeding the Illinois and Mississippi Canal; by Daniel W. Mead. The Author, Chicago, 1904. (Gives the value of water power destroyed by diversion of water.)

Kaukauma, Wis.

*IN RE DETERMINING AND FIXING THE JUST COMPENSATION TO BE PAID TO the Kaukauma Gas, Electric Light & Power Company by the City of Kaukauma, for the Property of Said Company Actually Used and Useful for the Convenience of the Public; Submitted Feb. 6, 1911, Decided Dec. 26, 1911 In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 8, p. 417. Madison, Wis., 1912. (On the value of a water-power lease.)

Kennebec River.

WATER-POWER OF CARATUNK FALLS, KENNEBEC RIVER, MAINE; by Samuel McElroy. *Transactions,* American Society of Mechanical Engineers, v. 17, p. 58 (1895-96). (On the relative cost of steam and water power.)

——Abstract. *Engineering News,* v. 34, p. 422 (Dec. 26, 1895).

Nashua River Paper Co.

NASHUA RIVER PAPER COMPANY VS. COMMONWEALTH OF MASSACHUSETTS. 4 v. Wright & Potter Printing Co., Boston, 1901. (On damages to be awarded for drawing off the water flowing by the plaintiff's mills.)

Newton, N. J.

AN IMPORTANT DECISION UPON A MILL OWNER'S SUIT TO COLLECT DAMages for the Diversion of Water. (Letter); by Louis L. Tribus. *Engineering News,* v. 43, p. 228 (April 5, 1900). (Gives text of decision in the case at Newton, N. J.)

NOTES ON NEWTON, N. J., WATER WORKS CONSTRUCTION AND LITIGATION; by Louis L. Tribus. *Journal,* New England Water Works Association, v. 23, p. 145 (June, 1909). (Decision of Court as to valuation of water power diverted for Newton, N. J., Water-Works.)

Niagara Falls.

COURT OF APPEALS: THE PEOPLE OF THE STATE OF NEW YORK, EX REL. Niagara Falls Hydraulic Power and Manufacturing Company, Appellant, Against State Board of Tax Commissioners, Respondents: Respondents' Points. Buffalo, 1911. (On valuation of property of the Niagara Falls Hydraulic Power Co.)

COURT OF APPEALS: THE PEOPLE OF THE STATE OF NEW YORK, EX REL. the Niagara Falls Hydraulic Power and Manufacturing Company, Appellant, *versus* the State Board of Tax Commissioners, Respondents, John L. Romer, Counsel for Appellant: Points for Appellant. Buffalo, 1910. (Relates to valuation of property of the Niagara Falls Hydraulic Power Co.)

SUPREME COURT, ERIE COUNTY: THE PEOPLE OF THE STATE OF NEW YORK, *ex rel.* the Niagara Falls Hydraulic Power & Manufacturing Company, against the State Board of Tax Commissioners. no place, no date. (Decision in regard to the valuation of property of the Niagara Falls Hydraulic Power Co.)

WATER POWER AT NIAGARA FALLS; by Samuel McElroy. *Journal,* Association of Engineering Societies, v. 4, p. 395 (Sept., 1885). (Estimation of the value of water power by Commissioners to award damages.)

WATER POWER—SPECIAL CASES—(*Continued*).

Troy, N. Y.

ABSTRACT FROM THE REPORT OF THE WATER COMMISSIONERS, TROY, N. Y., Damages to Mill Powers; by William G. Raymond. *Journal*, New England Water Works Association, v. 13, p. 152 (Dec., 1898). (On the method of estimating value of water power; cost of damages.)

Waltham, Mass.

WATER POWER, ITS MEASUREMENTS AND VALUE, WITH DATA RESPECTING Damages Awarded; by George A. Kimball. *Journal*, Association of Engineering Societies, v. 13, p. 71 (Feb., 1894). (Paper read before the Boston Society of Civil Engineers; some of the facts presented in evidence before the commission to award damages in the City of Waltham, Mass.)

Wausau, Wis.

*FRANK B. L. FULLMER VS. WAUSAU STREET RAILROAD COMPANY; Decided April 1, 1910. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 5, p. 125. Madison, Wis., 1911. (Gives basis of determining value of water power.)

Worcester, Mass.

KETTLE BROOK AND BLACKSTONE VALLEY MILL OWNERS, PETITIONERS, VS. City of Worcester. 5 v. Worcester, 1899. (Final arguments in a suit on the loss of power from the diversion of water.)

WATER-WORKS—GENERAL.

THE APPRAISAL AND DEPRECIATION OF WATER WORKS AND SIMILAR PROPerties; by William H. Bryan. *Journal*, Association of Engineering Societies, v. 39, p. 336 (Dec., 1907). (Forty-five pages.)

——Abstract. Depreciation Allowances for Various Public-Service Industries. *Engineering News*, v. 59, p. 96 (Jan. 23, 1908).

THE APPRAISAL OF PLANTS FOR PUBLIC SERVICES; by Nicholas S. Hill, Jr. *Engineering Record*, v. 43, p. 546 (June 8, 1901). (On methods of evaluation of water-works, etc., by the city.)

THE APPRAISAL OF WATER WORKS PROPERTIES WITH SPECIAL REFERENCE to the Reproduction Method. *Engineering and Contracting*, v. 39, p. 420 (April 9, 1913). (Paper read by Douglas A. Graham before the Illinois Water Supply Association.)

——*Engineering News*, v. 69, p. 677 (April 3, 1913).

——*Engineering Record*, v. 67, p. 532 (May 10, 1913).

THE ARBITRATION OR APPRAISAL OF THE VALUE OF PUBLIC UTILITIES; by Daniel W. Mead. *Proceedings*, American Water Works Association, v. 22, p. 132 (1902). (On the appointment of boards, duties of appraisers, evidence on the part of the company and of the municipality, and basis of valuation.)

CONSTRUING CERTAIN CLAUSES IN MUNICIPAL FRANCHISES; by John W. Hill. *Proceedings*, American Water Works Association, v. 19, p. 223 (1899). (On the value of water-works plants.)

——Abstract. *Engineering Record*, v. 39, p. 594 (May 27, 1899).

DEPRECIATION; by John W. Alvord. *Proceedings*, American Water Works Association, v. 23, p. 473 (1903). (Takes up the physical depreciation of pumping engines, stand-pipes, boilers, etc.; fifty-one pages.)

DEPRECIATION AS APPLIED TO WATER WORKS PROPERTIES; by Morris Knowles. no place, 1910. (Eighteen pages.)

DEPRECIATION CHARGES. (Letter): by Charles W. Helwick. *Engineering Record*, v. 59, p. 672 (May 29, 1909). (On valuation of water-works; very brief.)

DEPRECIATION IN CAST IRON PIPE. *Municipal Engineering*, v. 41, p. 211 (Sept., 1911). (Estimates for purpose of valuation.)

DEPRECIATION IN WATER WORKS ACCOUNTS, WITH REFERENCE TO UNIform Reports; by Harvey S. Chase. *Journal*, New England Water Works Association, v. 24, p. 305 (June, 1910). (Discusses depreciation in general as well as its relation to accounts; twenty-six pages.)

——Abstract. *Engineering-Contracting*, v. 33, p. 598 (June 29, 1910).

——Editorial. Depreciation and Sinking Fund Accounts. *Municipal Engineering*, v. 39, p. 26 (July, 1910).

DEPRECIATION IN WATER WORKS OPERATION AND ACCOUNTING; by Leonard Metcalf. *Journal*, New England Water Works Association, v. 24, p. 442 (Dec., 1910). (Thirty pages, with diagrams.)

WATER-WORKS—GENERAL—(*Continued*).

——Abstracts. *Engineering News*, v. 64, p. 482 (Nov. 3, 1910); Methods of Computing Depreciation of and Reasonable Assumptions as to Period of Useful Life of Water Works. *Engineering and Contracting*, v. 34, p. 434 (Nov. 16, 1910).

——Discussion. Methods of Making Computations for Depreciation in Public Utility Plants. *Engineering-Contracting*, v. 34, p. 590 (Dec. 28, 1910).

A DISCUSSION OF DEPRECIATION AND A COMPARISON OF RATES AND BOOK-keeping Methods of Municipally and Privately Owned Water Works. *Proceedings*, American Water Works Association, v. 32, p. 325 (1912). (Discusses report of Committee on Depreciation; twenty-two pages.)

——Abstract. Depreciation; by John W. Alvord. *Engineering Record*, v. 65, p. 670 (June 15, 1912).

THE FINANCIAL MANAGEMENT OF WATER-WORKS; by E. Kuichling. *Transactions*, American Society of Civil Engineers, v. 38, p. 1 (Paper 809. Dec., 1897). (Discusses annual expenses of water-works, including depreciation fund, yearly extensions, minor betterments, and future additions.)

THE FINANCIAL MANAGEMENT OF WATER WORKS; by Freeman C. Coffin. *Journal*, New England Water Works Association, v. 11, p. 63 (Sept., 1896). (Gives tables of water-works statistics; original cost, cost of annual maintenance, etc.)

FINANCIAL QUESTIONS IN WATER-WORKS VALUATION; by John W. Alvord. *Proceedings*, American Water Works Association, v. 22, p. 142 (1902). (On the business value, the franchise value and the fair return.)

——Abstracts. *Engineering Record*, v. 46, p. 30 (July 12, 1902); *Engineering News*, v. 47, p. 509 (June 19, 1902).

THE GOING VALUE OF WATER WORKS; by Leonard Metcalf and John W. Alvord. *Transactions*, American Society of Civil Engineers, v. 73, p. 334 (Paper 1199. Sept., 1911). (Sixty-six pages.)

METHOD OF ARBITRATION WITH REFERENCE TO VALUE OF WATER WORKS Plants; by Peter Milne. *Proceedings*, American Water Works Association, v. 17, p. 25 (1897). (On the tangible property and its value, value of franchise, and their relation; two and one-half pages.)

MUNICIPAL WATER SUPPLY REVENUE; by James L. Tighe. *Journal*, New England Water Works Association, v. 18, p. 352 (Dec., 1904). (On taxation; refers to the proper valuation of water-works.)

THE NECESSARY ELEMENTS FOR WATER-WORKS VALUATION; by John W. Alvord. *Engineering News*, v. 63, p. 286 (March 10, 1910). (Paper read before the Indiana Sanitary and Water Supply Association; outlines four methods of valuing public utility property which have been upheld by the Courts, and discusses in detail the valuation by reproduction.)

NOTES ON GOING VALUE AND METHODS FOR ITS COMPUTATION; by John W. Alvord. *Proceedings*, American Water Works Association, v. 29, p. 184 (1909). (Contains data on the valuation of water-works properties; ninety-five pages.)

——Abstract. *Engineering-Contracting*, v. 32, p. 95 (Aug. 4, 1909).

THE PRINCIPLES GOVERNING THE VALUATION FOR RATE FIXING PURPOSES of Water Works Under Private Ownership; by Arthur L. Adams. *Journal*, Association of Engineering Societies, v. 36, p. 37 (Feb., 1906). (On the valuation of water-works by the Government; paper read before the Pacific Coast Engineering Congress.)

——*Engineering Record*, v. 52, p. 153 (Aug. 5, 1905).

RATING OF WATER UNDERTAKINGS; by F. J. Bancroft. *Transactions*, British Association of Waterworks Engineers, v. 5, p. 26 (1900). (Discusses the taxation and valuation of English water-works, with reference to the Valuation (Metropolis) Act, 1869.)

——*Journal of Gas Lighting*, v. 76, p. 24 (July 3, 1900).

SOME FUNDAMENTAL CONSIDERATIONS IN THE DETERMINATION OF A REASON-able Return for Public Fire Hydrant Service; by Metcalf, Kuichling and Hawley. *Proceedings*, American Water Works Association, v. 31, p. 55 (1911). (Contains data on the valuation of water-works.)

TABLE SHOWING LIFE AND DEPRECIATION OF WATER WORKS PLANTS. *Municipal Journal and Engineer*, v. 24, p. 558 (May 6, 1908).

TOWN WATER-WORKS FROM A FINANCIAL STANDPOINT; by W. L. Hedenberg. *Municipal Engineering*, v. 15, p. 341 (Dec., 1898). (On value of a plant after several years' use; theoretical.)

VALUATION OF WATER WORKS; by Alton D. Adams. *Municipal Journal*, v. 32, p. 942 (June 20, 1913). (Cost of reproduction, value of plant site, distribution system, adequateness of plant, depreciation.)

WATER-WORKS—GENERAL—(*Continued*).

VALUATION OF WATER-WORKS PROPERTIES; by Charles E. Burdick. *Engineering-Contracting*, v. 23, p. 238 (Oct. 23, 1907). (On physical value, depreciation, going value and franchise value; abstract of paper read before Wisconsin League of Municipalities; four pages.)

——*Municipal Journal and Engineer*, v. 23, p. 302 (Sept. 11, 1907).

VALUATION OF WATER-WORKS PROPERTY; by Wynkoop Kiersted. *Transactions*, American Society of Civil Engineers, v. 38, p. 115 (Paper 813. Dec., 1897). (100 pages, including discussion.)

WATER-WORKS APPRAISALS; by Burns and McDonnell. *Engineering Record*, v. 59, p. 616 (May 15, 1909). (Gives brief descriptions of appraisals in nine different cities.)

WATER-WORKS MANAGEMENT AND MAINTENANCE; by Winfred D. Hubbard and Wynkoop Kiersted. John Wiley & Sons, New York, 1907. (Contains a chapter on franchise, water rates, and depreciation.)

WATER-WORKS—SPECIAL CASES.

Antigo, Wis.

***GEORGE W. HILL ET AL. VS. ANTIGO WATER COMPANY**; Submitted June 29, 1908, Decided August 3, 1909. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 3, p. 623. Madison, Wis., 1910. (Gives methods of valuation of water-works plant.)

Appleton, Wis.

***CITY OF APPLETON VS. APPLETON WATER WORKS COMPANY**; Decided May 14, 1910. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 5, p. 215. Madison, Wis., 1911. (Discusses the determination of the present value and reproduction of physical property, value of franchises, etc.)

——The Appleton Water-Works Decision. *Engineering Record*, v. 62, p. 158 (Aug. 6, 1910). (Two pages.)

——Decision of the Railroad Commission of Wisconsin in the Appleton Water-Works Case. *Engineering News*, v. 63, p. 697 (June 16, 1910). (Two pages.)

***IN RE DETERMINING AND FIXING A JUST COMPENSATION TO BE PAID TO** the Appleton Water Works Company by the City of Appleton for the Taking of the Property of Said Company; Submitted Oct. 24, 1910, Decided Dec. 7, 1910. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 6, p. 97. Madison, Wis., 1912. (Detailed summary of valuation of physical property of the Appleton Water-Works Co., five-year average, franchise value and going value.)

Ashland Wis.

***CITY OF ASHLAND VS. ASHLAND WATER COMPANY**; Decided Nov. 1, 1909. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 4, p. 273. Madison, Wis., 1910.

Augusta, Me. See Maine.

Baltimore, Md.

A RETROSPECT OF AN ARBITRATION ON THE VALUE OF A WATER WORKS; by Albert H. Wehr. *Proceedings*, American Water Works Association, v. 26, p. 361 (1906). (The Mayor and City Council of Baltimore against the Baltimore County Water & Electric Co.; shows method and principle applied to appraisal of the property.)

——Abstract. Arbitration on the Value of a Water-Works. *Municipal Engineering*, v. 31, p. 135 (Aug., 1906).

Beloit, Wis.

***CITY OF BELOIT VS. BELOIT WATER, GAS AND ELECTRIC COMPANY**; Decided July 19, 1911. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 7, p. 201. Madison, Wis., 1912. (Includes appraisal of the physical property of the Water-Works Department.)

——Fixing Normal Operating Costs; by Frank A. Newton. *Engineering Record*, v. 65, p. 258 (March 9, 1912). (Comments on the decision of the Wisconsin Railroad Commission in the case of the City of Beloit *vs.* the Beloit Water, Gas & Electric Co.)

Birmingham, Ala.

THE MERIDIAN CASE; by W. J. Milner. *Proceedings*, American Water Works Association, v. 16, p. 204 (1896). (Concerning the appraisal of the Birmingham, Ala., Water-Works, on their purchase by the City.)

Brunswick, Me. See Maine.

WATER-WORKS—SPECIAL CASES—(*Continued*).

California.

*UNIFORM CLASSIFICATION OF ACCOUNTS FOR WATER CORPORATIONS PRE-scribed by the Railroad Commission of the State of California; Adopted Oct. 23, 1912; Effective Jan. 1, 1913. Sacramento, 1912.

Chicago, Ill

THIRTY-FOURTH ANNUAL REPORT OF THE DEPARTMENT OF PUBLIC WORKS to the City Council of the City of Chicago for the Year Ending Dec. 31, 1909. pp. 320, 321. Chicago, 1911. (Gives tables of appraisement of water-works equipment and percentage of depreciation.)

Chippewa Falls, Wis.

*T. J. CUNNINGHAM ET AL. VS. CHIPPEWA FALLS WATER WORKS AND LIGHT-ing Company: In Re Investigation by the Railroad Commission of Wisconsin of Rates Charged by the Chippewa Falls Water Works and Lighting Company; In Re Valuation of the Property of the Chippewa Falls Water Works and Lighting Company; Decided June 14, 1910. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 5, p. 302. Madison, Wis., 1911. (Consideration of factors affecting plant value, going value, working capital and accruing depreciation.)

Contra Costa, Cal.

VALUATION OF THE WORKS OF THE CONTRA COSTA WATER COMPANY. *Engineering Record*, v. 43, p. 516 (June 1, 1901). (Review of a decision in a California Court in which the value of the property of a water-works company is placed at two and one-half times its cost.)

Denver, Colo.

REPORT OF THE BOARD OF APPRAISERS AND ARBITRATORS UPON THE PROP-erty of the Denver Union Water Company, March 20, 1909. Denver, 1909. (Report made to the Mayor and City Council, giving estimates on real and personal property; forty-six pages.)

Fond du Lac, Wis.

*IN RE DETERMINING AND FIXING JUST COMPENSATION TO BE PAID TO THE Fond du Lac Water Company by the City of Fond du Lac for the Property of Said Company Actually Used and Useful for the Convenience of the Public; Submitted April 15, 1910, Decided Aug. 19, 1910. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 5, p. 482. Madison, Wis., 1911. (Discusses the original value of plant depreciation, etc.)

——Valuation of the Fond du Lac Water-works. *Engineering Record*, v. 62, p. 275 (Sept. 2, 1910). (Reviews the principles on which the Railroad Commission of Wisconsin based its findings; two pages.)

Freeport, Ill.

A COMPARATIVE STUDY OF THE FOUR PRINCIPAL METHODS OF APPRAISING the Value of Public Utilities with Special Reference to the Valuation of the Freeport (Ill.), Water Works Properties. *Engineering and Contracting*, v. 38, pp. 368, 396 (Oct. 2, 9, 1912). (The original cost method; the commercial or comparative method; the value of a plant as found by the market value of its securities; and the cost of reproducing the property at the present normal prices of material and labor.)

Gloucester, Mass.

THE APPRAISAL OF THE GLOUCESTER WATER-WORKS. *Engineering Record*, v. 40, p. 264 (Aug. 19, 1898). (A review of the principles adopted by the commissioners appointed to hear testimony and appraise the value of a private water company.)

——Appraisal of the Gloucester Water-Works. *Engineering Record*, v. 44, p. 121 (Aug. 10, 1901). (A decision of the Supreme Judicial Court of the Commonwealth of Massachusetts on the valuation of water-works.)

Great Britain.

THE VALUATION OF WATER-WORKS UNDERTAKINGS ON TRANSFER TO MU-nicipal Authorities; by E. J. Silcock. *Surveyor and Municipal and County Engineer*, v. 43, p. 920 (June 13, 1913). (Paper read before the Institution of Water Engineers; general principles on valuation of water-works property in Great Britain.)

Indianapolis, Ind.

REPORT OF THE BOARD OF PUBLIC WORKS, INDIANAPOLIS, 1898, p. 13. Indianapolis, 1898. (Contains report upon the physical condition and value of the property of the Indianapolis Water Co.)

WATER-WORKS—SPECIAL CASES—(*Continued*).

Janesville, Wis.

*CITY OF JANESVILLE VS. JANESVILLE WATER COMPANY; Decided August 17, 1911. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 7, p. 628. Madison, Wis., 1912. (Contains summary showing value of each class of property in revised valuation of physical property brought down to Jan. 1, 1910.)

Kansas. See Missouri.

Knoxville, Tenn.

THE KNOXVILLE WATER CASE. *Electric Railway Journal*, v. 33, p. 280 (Feb. 13, 1909). (Decision of U. S. Supreme Court; contains material on valuation and depreciation; one and one-half pages.)

——Editorial. Depreciation of Plant and Fair Rates for Public Service. *Engineering Record*, v. 59, p. 197 (Feb. 20, 1909). (Comments on the decisions of the Supreme Court in the Knoxville water case.)

PROVISION FOR DEPRECIATION BY PUBLIC UTILITY CORPORATIONS. (Letter); by W. H. Winslow. *Engineering News*, v. 61, p. 251 (March 4, 1909). (Comment on decision of the Supreme Court in the Knoxville water case.)

SUPREME COURT DECISION IN THE KNOXVILLE WATER CASE. *Electrical World*, v. 53, p. 386 (Feb. 11, 1909). (Two pages.)

VALUATION OF PUBLIC UTILITY PROPERTIES. *Electrical World*, v. 53, pp. 509, 692, 740, 928, 1036 (Feb. 25, March 18, 25, April 15, 29, 1909). (Discussion between W. H. Winslow and F. E. Haskell in relation to the reasoning of the U. S. Supreme Court as to depreciation, in the Knoxville water case.)

Lake Forest, Ill.

OUTLINE OF A CONTRACT BETWEEN A CITY AND A WATER-WORKS COMpany. *Municipal Engineering*, v. 36, p. 247 (April, 1909). (Ordinance rejected by City Council of Lake Forest, Ill.; included provision for valuation of property according to the British plan.)

London, England.

LONDON WATER-WORKS ACQUIREMENT; by R. Price-Williams. *Engineering*, v. 77, p. 544 (April 15, 1904). (Concerning the report of the Court of Arbitration on the valuation of eight water companies acquired by the Water Board.)

Los Angeles, Cal.

ALLOWANCES FOR DEPRECIATION IN THE PIPE SYSTEM OF THE LOS ANgeles Water-Works. *Engineering News*, v. 41, p. 283 (May 4, 1899). (Gives total valuation of the distribution system and details of depreciation established for different varieties of pipe.)

Madison, Wis.

*CHRISTIAN DICK ET AL. VS. BOARD OF WATER COMMISSIONERS OF THE City of Madison, In Re Valuation of the Plant of the Madison Municipal Water Works; Decided Nov. 11, 1910. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 5, p. 731. Madison, Wis., 1911. (A valuation of the Madison water plant undertaken by the Engineers of the Commission.)

——The Method of Making Water Rates Ordered in Wisconsin. *Engineering Record*, v. 63, p. 28 (Jan. 7, 1911). (Valuation of the water-works of Madison, Wis., to assist in determining rates.)

Maine.

A COURT RULING ON THE BASIS FOR APPRAISAL OF A WATER-WORKS PLANT. *Engineering News*, v. 49, p. 75 (Jan. 22, 1903). (Contains instructions to the appraisers appointed to fix the price of water-works property at Waterville, Fairfield, Winslow, Benton, and Mt. Vernon, in Maine, to be taken by the Kennebec Water District.)

MAINE WATER DISTRICTS AND APPRAISERS; by Harvey D. Eaton. *Journal*, New England Water Works Association, v. 19, p. 147 (June, 1905). (Provisions of an act providing for the incorporation of the Kennebec Water District and the appraisal of the water-works of Waterville and Augusta, Me.)

NEW FEATURE IN WATER-WORKS APPRAISALS. (Editorial.) *Engineering News*, v. 54, p. 147 (Aug. 10, 1905). (Considers the relation between the Waterville and Augusta appraisals and the quality of the water supply.)

WATER WORKS VALUATION AND FAIR RATES IN THE LIGHT OF THE MAINE Supreme Court Decisions in the Waterville and Brunswick Cases; by Leonard Metcalf. *Transactions*, American Society of Civil Engineers, v. 64, p. 1 (Paper 1105. Sept., 1909). (111 pages, including discussion.)

——Editorial. Fair Rates for Water Service. *Municipal Engineering*, v. 36, p. 29 (Jan., 1909).

WATER-WORKS—SPECIAL CASES—(*Continued*).

Manitowoc, Wis.

*IN RE DETERMINING AND FIXING A JUST COMPENSATION TO BE PAID TO the Manitowoc Water Works Company by the City of Manitowoc for the Property of Said Company Actually Used and Useful to the Public; Submitted March 15, 1911, Decided June 27, 1911. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 7, p. 74. Madison, Wis., 1912. (Valuation of physical property and going value of the plant.)

VALUATION OF MANITOWOC WATER-WORKS. *Engineering Record*, v. 64, p. 40 (July 8, 1911). (Valuation made by the Wisconsin Railroad Commission.)

Marinette, Wis.

*CITY OF MARINETTE VS. CITY WATER COMPANY OF MARINETTE; Decided Dec. 14, 1911. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 8, p. 334. Madison, Wis., 1912. (The physical value of the property, the going value, and the apportionment of value between general and fire service.)

Missouri.

WATER-WORKS APPRAISEMENTS IN MISSOURI AND KANSAS; by Clinton S. Burns. *Engineering News*, v. 62, p. 115 (July 29, 1909). (A brief description of nine appraisements made for municipalities; one page.)

Mobile, Ala.

THE MOBILE WATER-WORKS APPRAISAL. (Letter); by J. M. Hazlehurst. *Engineering News*, v. 49, p. 412 (May 7, 1903).

WATER-WORKS APPRAISAL AT MOBILE, ALA. *Engineering News*, v. 49, p. 359 (April 23, 1903). (Report of Committee appointed by the City, in view of the purchase of the water-works by the City.)

——Editorial. *Engineering News*, v. 49, p. 368 (April 23, 1903).

New York, N. Y.

ACQUISITION BY NEW YORK CITY OF THE LARGER OF TWO WATER SYSTEMS of Staten Island; by Louis L. Tribus. *Proceedings*, American Water Works Association, v. 29, p. 557 (1909). (Estimates on the water-works by a commission of engineers giving physical values, going value, etc.)

Oconto, Wis.

*IN RE APPLICATION OF THE OCONTO CITY WATER SUPPLY COMPANY FOR Valuation of Its Property and Other Relief; Submitted Feb. 10, 1911, Decided Aug. 7, 1911. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 7, p. 497. Madison, Wis., 1912. (Gives tentative and final valuation of the physical property of the plant.)

Omaha, Nebr.

SOME RULES FOR WATER-WORKS APPRAISAL: OPINION OF U. S. SUPREME Court Delivered by Judge Lurton, in City of Omaha *vs.* Omaha Water Company. *Engineering Record*, v. 62, p. 293 (Sept. 10, 1910). (Two and one-half pages.)

Peoria, Ill.

REPORT TO THE MAYOR AND CITY COUNCIL ON WATER RATES FOR THE Plant Belonging to the Peoria Water Works Co., Peoria, Ill.; by Benezette and C. B. Williams. Peoria, 1910. (Treats of controlling principles of public utility values, Court decisions, valuations for sale and rate-making; with a table giving computation of going value of the Peoria Water-Works plant.)

VALUATION OF PHYSICAL PROPERTY OF THE PEORIA WATER CO. WITH A Discussion of Rate-Making and Reasonable Rates. *Engineering and Contracting*, v. 35, p. 192 (Feb. 15, 1911). (Serial includes tables of valuation.)

Quincy, Ill.

THE APPRAISAL OF THE QUINCY WATER-WORKS. *Engineering Record*, v. 50, p. 118 (July 23, 1904). (Report of appraisers appointed by City of Quincy, Ill., in relation to purchase of plant of Quincy Water Co.)

Richmond, Ind.

SOME NOTES AND FIGURES ON THE VALUATION OF THE WATER WORKS Plant at Richmond, Ind.; by Howard A. Dill. *Engineering-Contracting*, v. 33, p. 202 (March 2, 1910). (Gives actual estimates; from a paper before the Indiana Sanitary and Water Supply Association, 1910; one page.)

——Valuation of Water-Works System of Richmond, Ind.; by Howard A. Dill. *Municipal Engineering*, v. 38, p. 410 (June, 1910).

Rockford, Ill.

REPORT ON THE ENLARGEMENT AND EXTENSION OF THE WATER SUPPLY and Distribution System of the City of Rockford, Ill., p. 96; by John W. Alvord, Dabney H. Maury and Daniel W. Mead. Rockford, Ill., 1911. (Contains two and one-half pages on the valuation of the present plant and property.)

WATER-WORKS—SPECIAL CASES—(*Continued*).

San Antonio, Tex.

THE ADJUSTMENT OF WATER RATES. *Engineering Record*, v. 45, p. 127 (Aug. 9, 1902). (Some features of a valuation of the San Antonio, Tex., Water Works Co., made by Chester B. Davis.)

REPORTS ON WATER-WORKS RATES AND VALUATION AT SAN ANTONIO, TEX. *Engineering News*, v. 48, p. 233 (Sept. 25, 1902). (Report made by Chester B. Davis.)

Superior Water, Light & Power Co.

***ESTIMATING THE RATE OF REASONABLE RETURN FOR A PUBLIC UTILITY.** *Engineering and Contracting*, v. 39, p. 482 (April 30, 1913). (Argument of William H. Winslow, Vice-President of the Superior Water, Light & Power Co. before the Wisconsin Railroad Commission, giving analysis of the rate of fair return to be allowed on capital to be invested in public utilities.)

Syracuse, N. Y.

MUNICIPAL ACQUIREMENT OF PRIVATE WATER COMPANY PLANTS, AS Illustrated by the Syracuse, N. Y., Water Company Condemnation by the City; by Stephen E. Babcock. *Proceedings*, American Water Works Association, v. 13, p. 85 (1893). (Discusses actual values assigned in Syracuse Water-Works appraisal.)

——Abstract. Municipal Acquirement of the Plant of the Syracuse Water Co. *Engineering News*, v. 30, p. 207 (Sept. 14, 1893).

Valparaiso, Ind.

THE WATER-WORKS APPRAISAL CASE AT VALPARAISO, IND. (Editorial Note.) *Engineering News*, v. 49, p. 289 (April 2, 1903). (Value decided by the Court; basis of decision.)

Washburn, Wis.

***CITY OF WASHBURN VS. WASHBURN WATER WORKS COMPANY**; Decided Dec. 6, 1910. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 6, p. 74. Madison, Wis., 1912. (Contains tentative valuation of the physical property of the Company.)

Waterloo, Iowa.

STRANGE CASE OF WATER-WORKS APPRAISAL. (Editorial.) *Engineering Record*, v. 59, p. 502 (April 17, 1909). (Discusses estimates in the valuation of the Waterloo, Iowa, Water-Works made by A. Marston.)

THE VALUATION FOR CITY PURCHASE OF THE PROPERTY OF THE WATERLOO (Ia.) Water-Works Co.; by A. Marston. *Engineering News*, v. 61, p. 424 (April 22, 1909). (General explanation with abstract of explanatory report; one page.)

Waterville, Me. *See Maine.*

WATER-WORKS—UNVERIFIED REFERENCES.

DEPRECIATION OF WATER WORKS; by John W. Alvord. (Serial.) *Fire and Water Engineering*, v. 34, pp. 104, 144 (Aug. 22, Sept. 12, 1903).

KNOXVILLE WATER CO. VS. CITY OF KNOXVILLE: Report of Special Master; Decision of Judge Clark, U. S. Circuit Court, East. District of Tennessee, Northern Division, Aug. 19, 1904. Jan. 24, 1905.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

This Society is not responsible for any statement made or opinion expressed in its publications.

CONSTRUCTION PROBLEMS, DUMBARTON BRIDGE, CENTRAL CALIFORNIA RAILWAY.

Discussion.*

By Messrs. Theodore Belzner and E. J. Schneider.†

Theodore Belzner, Assoc. Am. Soc. C. E. (by letter).—The floating of the six approach spans into position, recalls to the writer operations of a similar nature on the Harlem River Ship Canal Bridge during the fall of 1905 and the summer of 1906. Mr. Belzner.

The author states that the average time required to place a span was about 2 hours, depending on the distance it had to be moved. More information concerning the itinerary of the work, such as rate of motion, distance floated, etc., for each operation, would be of interest.

In reference to the floating of the approach and draw-spans of the Harlem River Ship Canal Bridge at Kingsbridge, it may be of interest to state briefly the actual times required in the six operations of moving the old and placing the new spans.

The Department of Bridges of the City of New York issued a permit closing the Ship Canal Bridge to street travel for a total time of 5 days, of which not more than 3 days were to be consecutive. It was calculated that only 1 day would be necessary for moving each of the approach spans and that the draw-span operations could be completed in 3 days.

Prior to the removal of the old approach spans, the new spans were moved to points about 115 ft. east and west of their final positions (these movements consisting of a land and water operation). The two old spans were 100 ft. long and weighed 240 tons each; the two new spans were 100 and 112 ft. long, and weighed 330 and 380 tons,

* Continued from May, 1913, *Proceedings*.

† Author's closure.

Mr. Belzner. respectively. The old draw-span was 272 ft. long, weighed 900 tons, exclusive of cribbing, and was floated from Kingsbridge to the University Heights site, a distance of about 1 mile. The new draw-span was also 272 ft. long, weighed 1 500 tons (and with the cribbing nearly 2 000 tons), and was floated from 216th Street, a distance of ½ mile to its new site at Kingsbridge.

On October 19th, 1905, at 5 A. M., the south approach span operation was begun, and at 5.45 P. M. the first vehicle passed over the bridge, the time elapsed being 12¾ hours. On November 6th, at 1.30 P. M., the north approach operation was begun, and at 10.15 P. M. the bridge was opened to surface traffic, the time elapsed being 8¾ hours. These operations delayed travel 21½ hours, or 26½ hours less than the calculated time.

The draw-span operations extended from 10.15 A. M. on June 14th, 1906, to 5.20 A. M. on June 17th, the time elapsed being 2 days, 19 hours, and 5 min., or 4 hours and 55 min. less than the stipulated time.

In other words, the entire operations were accomplished in 3 days, 16 hours and 35 min., or 1 day, 7 hours and 25 min. less than the 5-day limit.

Mr. Schneider. E. J. SCHNEIDER, M. AM. SOC. C. E. (by letter).—It has been particularly gratifying to the writer to note the interest which has been taken in this paper. Certain points are raised by Mr. Rights regarding the double-ended traveler: The single booms at each end of the traveler were designed especially for facility in erection of the draw-span, which was erected as symmetrically as practicable, from the center toward each end, on top of the protection work which had been designed to act as falsework. Had the traveler not been double-ended, additional falsework would have been required at one end of the draw-span protection and at the site of the erection of the six 180-ft. spans.

Answering Mr. Coombs in regard to piles and pile-driving: The specifications called for lengths of from 60 to 120 ft., the diameter of the tips to be 9 or 10 in., the usual requirements by the Southern Pacific Company for ordinary work, and no change was made in them for this particular piece of construction. Pacific Coast piles, no doubt, are larger than those ordinarily used in the East. All piles used at Dumbarton were peeled.

Pile-driving is mainly a matter of judgment. The lengths of the piles at Dumbarton were determined from actual test driving on the line across the Bay, and from the records of the borings made by the Spring Valley Water Company on the line of its submerged pipe a short distance from, and approximately parallel to, the bridge.

The points brought up by Mr. Belzner, in reference to the average rate of motion, distance floated, etc., for each operation, can best be

answered by a copy of the record for floating the six spans from the falsework to the piers, Table 1. Mr. Schneider.

TABLE 1.—Record for Floating Six 180-Foot Spans from Falsework to Piers, for the Dumbarton Bridge.

The Span Numbers Run from East to West, Numbering the Entire Draw-Bridge as Span No. 4.

Date.	Span No.	Hour.		Time interval.	Approximate distance floated, in feet.
		Clear of falsework.	Landed on piers.		
September 16th, 1909.....	3	12.25 P. M.	2.00 P. M.	1 hr. 35 min.	700
September 26th, 1909.....	2	9.30 A. M.	11.00 A. M.	1 " 30 "	500
October 14th, 1909.........	1	10.55 A. M.	12.15 P. M.	1 " 20 "	300
November 7th, 1909.......	5	8.25 A. M.	9.40 A. M.	1 " 15 "	1 200
December 9th, 1909.	6	7.45 A. M.	9.50 A. M.	2 " 05 "	1 400
December 11th, 1909......	7	10.05 A. M.	11.05 A. M.	2 " 00 "	1 600

The average rate of motion for each operation was a little less than 1 mile per hour.

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COLORADO RIVER SIPHON.

Discussion.*

By H. T. Cory, M. Am. Soc. C. E.

H. T. Cory, M. Am. Soc. C. E. (by letter).—The writer is particularly glad that this paper has been presented, partly because of a personal interest in the entire Lower Colorado (and therefore including the Yuma Project), and also because the Colorado River Siphon is a most interesting piece of work, not only from one point of view, but from many. It is to be regretted, however, that the author did not make it but a part of a paper on the entire Yuma Project—for the preparation of which he is evidently well qualified, judging by the clear-cut, systematic, and, with one exception, comprehensive account, he has given of this portion—and that he did not say anything about costs, one of the most vital phases. Possibly the cost data were not assembled, classified, and available in a satisfactory form when the paper was submitted, but as it is now 11 months since water was turned through the siphon—the author gives such date as June 30th, 1912—it is earnestly hoped that he or some other member of the Service, will present to the Society the complete cost sheets, with distributions, in connection with this paper. Mr. Cory.

On page 418† it is stated that the present flow through the siphon is "about 300 sec-ft., of which about 100 are wasted to the river on the Arizona side. The velocity in the shafts and tunnel, therefore, is low, being slightly greater than the silting velocity. Soundings taken in the shafts indicate that little or no silting has taken place."

* This discussion of the paper by George Schobinger, Jun. Am. Soc. C. E. (now Assoc. M. Am. Soc. C. E.), published in March, 1913, *Proceedings*, and presented at the meeting of May 7th, 1913, is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† *Proceedings*, Am. Soc. C. E., for March, 1913.

Mr. Cory. The cross-sectional area of the California shaft, 17 ft. in diameter, is 226.98 sq. ft.; of the tunnel, 14 ft. in diameter, 153.94 sq. ft.; and of the Arizona shaft, 23 ft. in diameter, 415.48 sq. ft. A flow of 300 sec-ft., therefore, would give velocities of 1.321, 1.936, and 0.722 ft. per sec., respectively. It is a little surprising, under all the circumstances, particularly in reference to the latter velocity, that it is greater than the silting velocity of the water carried by the main canal at the Colorado Siding.

The method of removing all but the finer silt at Laguna Dam is undoubtedly effective, and a considerable percentage of particles held in suspension just below the head-works is probably deposited in the 14 miles of 80-ft. bottom width canal leading thence to the siphon, especially while so small a quantity of water is flowing. Nevertheless, experience in the Imperial Valley Project, with the same river water, is that very considerable silt deposition occurs at points distant from 60 to 80 miles, in canals with velocities of 1.35 ft. per sec., and even greater, during flood stages in the river.

It is to be hoped that further experience will confirm the opinion that little or no trouble from silting will develop; nevertheless, for a few years, the operation and maintenance costs of the siphon will be watched by many with much interest.

The writer also hopes that the discussion will bring out the considerations and data which caused the adoption of the various diameters of the Arizona shaft, the tunnel, and the California shaft, and particularly as to the weight assigned, in so doing, to the silt problem.

AMERICAN SOCIETY OF CIVIL ENGINEERS

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PAPERS AND DISCUSSIONS

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STATICAL LIMITATIONS UPON THE STEEL REQUIREMENT IN REINFORCED CONCRETE FLAT SLAB FLOORS.

Discussion.*

By Messrs. L. J. Mensch, C. A. P. Turner, Edward Godfrey, H. T. Eddy, A. W. Buel, E. G. Walker, and William W. Crehore.

L. J. Mensch, M. Am. Soc. C. E. (by letter).—This paper invites a timely discussion of the design of the so-called flat slab floors. It seems that the best firms in America have a fairly good knowledge, based on expensive tests, of the maximum stresses which enter into the design of such plates, yet they cannot convince the conservative engineer or architect that their designs are not a gamble, and that many of their structures will not show serious defects sooner or later. To the writer's knowledge, the responsible firms which make a specialty of designing and building such floors do not use higher stresses than the author claims to find by static methods. His paper, however, will not advance our knowledge of the design of such floors, as he assumes a certain relation of positive and negative moments, and fails to prove that they may exist. Mr. Mensch.

The writer will endeavor to develop a rational method of designing flat floors, practically without the help of the higher mathematics. For this purpose he will consider the floor to consist of two systems of slabs, at right angles to each other and continuous over the supports. As shown in Fig. 7, each slab carries one-half of the panel load of each panel, and is of a width equal to the distance from center

* This discussion (of the paper of John R. Nichols, Jun. Am. Soc. C. E., published in April, 1913, *Proceedings*, and presented at the meeting of May 21st, 1913), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

Mr. Mensch.

to center of columns. The theory of continuous beams will be applied to a few of the most important cases.

Case I.—Fig. 8.—Continuous Slab on Four Supports; Only the Center Panel Loaded, by the Triangular Load, $\frac{W}{2} = \frac{W l^2}{2}$.—

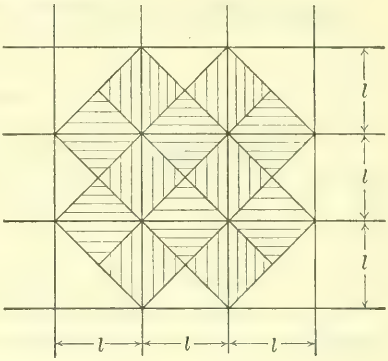

FIG. 7.

One easily finds the reaction at $A = -\frac{1}{32} W$,

and the reaction at $B = \frac{9}{32} W$.

The moment over the support, $B = A l = -\frac{1}{32} W l$.

The moment in the center of the loaded panel $= A l + B \frac{l}{2} - \frac{W}{4} \frac{l}{6} = \frac{5}{96} W l = \frac{1}{19.2} W l$.

Case II.—Fig. 9.—Continuous Slab on Four Supports; Only the Outside Panels Loaded. Load on Each Panel, $\frac{W}{2}$.—

The reaction at $A = \frac{7}{32} W$.

The reaction at $B = \frac{9}{32} W$.

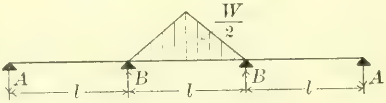

FIG. 8.

The moment in the center of the loaded panels $= \frac{13}{192} W l$ $= \frac{1}{14.8} W l$.

The moment at B and for the entire center panel $= A l - \frac{W}{2} \frac{l}{2} = -\frac{W l}{32}$.

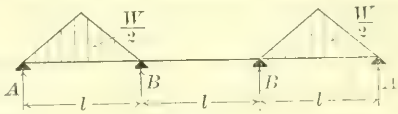

FIG. 9.

Case III.—Fig. 10.—Continuous Slab on Four Supports; Each Panel Loaded by a Triangular Load, $\frac{W}{2}$.—

The reaction at $A = \frac{3}{16} W$.

The reaction at $B = \frac{9}{16} W$.

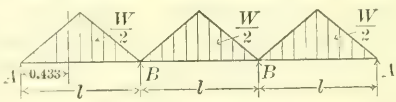

FIG. 10.

The maximum moment at 0.433 l from $A = \frac{W l}{18.5}$.

The moment over $B = Al - \frac{W}{2}\ \frac{l}{2} = -\frac{Wl}{16}$. Mr. Mensch.

The moment in the center of the center panel

$$= B\ \frac{l}{2} - \frac{W}{4}\ \frac{l}{6} - \frac{Wl}{16} = \frac{Wl}{48}.$$

Case IV.—As in Case I, but With an Infinite Number of Panels; and the Triangular Load, $\frac{W}{2}$, Applied to the Center Panel.—The bending moments, over the support, as well as in the center of the loaded panel, are the same as given under Case I.

Case V.—As in Case III, but With an Infinite Number of Panels.—The bending moments over the central supports $= \frac{W\,l}{19.2}$. The bending moments in the center of the center panel $= \frac{W\,l}{32}$. In this case the outside panels have about the same maximum moments as the outside panels in Case III, and the same as the moments over the second supports. The maximum moments in the second panels from the outside $= \frac{W\,l}{35.5}$, and those over the third supports $= \frac{W\,l}{22.4}$.

As an example, consider a continuous slab on four supports, 20 ft. from center to center, having a dead load of 125 lb. per sq. ft., and calculated for a live load of 250 lb. per sq. ft.

W for the dead load $= 125 \times 400 = 50\,000$ lb.
W for the live load $= 250 \times 400 = 100\,000$ "

For Case I, the moment in the center of the center panel from live load $= \frac{100\,000 \times 20}{19.2} = 104\,200$ ft-lb. For Case III, the moment in the center of the center panel from dead load $= \frac{50\,000}{48} \times 20 = 20\,800$ ft-lb., or a total bending moment of 125 000 ft-lb.

For Case II, the moment in the center of the outside panel from live load $= \frac{100\,000 \times 20}{14.8} = 135\,000$ ft-lb. For Case III, the moment in the center of the outside panel from dead load $= \frac{50\,000}{18.5} \times 20 = 54\,000$ ft-lb., or a total bending moment of 189 000 ft-lb., or 50% greater than for the center panel.

The moment over the support, B, is greatest for Case III, and equals $\frac{150\,000 \times 20}{16} = 188\,000$ ft-lb., or the slab must be just as strong over the supports as in the center.

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The entire inside panel is subject to a negative moment from 1.1 for Case II, which moment $= \dfrac{100\,000 \times 20}{32} = 62\,500$ ft-lb., which in the center of the panel is reduced by the dead load moment of $\dfrac{50\,000 \times 20}{48}$ $= 20\,800$ ft-lb. These high negative moments cannot be neglected by a responsible designer. The author and most of the designers seem to consider only Case V, for which the moment in the center of the center panel $= \dfrac{150\,000 \times 20}{32} = 94\,000$ ft-lb., and the moment over the supports of the center panel $= \dfrac{150\,000 \times 20}{19.2} = 156\,000$ ft-lb., or considerably less than in the foregoing cases, or in the outside panels of Case V.

The moments heretofore given are for the entire slab, having a width $= l$. The assumption made by the author is that the stresses are distributed uniformly. By dividing the width of the panel into, say, ten units, it can be shown that a parabolic distribution of the entire moment, for the sizes of caps ordinarily used, is as near an assumption as can be made. See Fig. 11. Then the moments in the middle portion of the slab are 25% greater than the average moments and 2.5 times as great as at the edge of the slab. The foregoing computations are only adaptable to flat slabs with caps which have universal joints over the centers of the columns. This is not the case in practice; on the contrary, the columns are well connected with the floors, and nearly always have a larger moment of inertia than the floor slab of a total width $= l$. Besides, the height of the columns in most cases is considerably less than the span of the floor, and, therefore, the columns will offer a greater resistance to a change of angle over the supports than can be expected from the continuous action of the floor when only one panel is loaded. As a rule, there are columns on top as well as below the floor, and these will increase further the arch action which is to be considered.

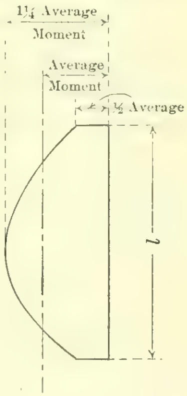

FIG. 11.

It will now be assumed that two panels are loaded side by side, as in Fig. 12, and that the two columns and the flat slab of a width, l, form a hingeless arch construction, as shown in Fig. 13.

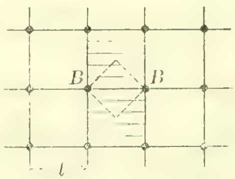

FIG. 12.

To facilitate the calculation, it will be assumed that the columns cannot change their inclination at A. Two unknown values have to be found, the thrust, T, and the moment, Ma.

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Let I = the moment of inertia of the column;
I_1 = the moment of inertia of the floor slab of the width, l;
h = the story height;
l = the distance from center to center of columns;
$n = \frac{h}{l} \frac{I_1}{I}$.

It is known, from the theory of beams, that the column, AB, which is subject only to a force, T, and a moment, Ma, must have its point of inflection at $\frac{1}{3}$ h from A, because the column cannot change its angle at A, as has been assumed. It immediately follows that $Ma = \frac{T\,h}{3}$.

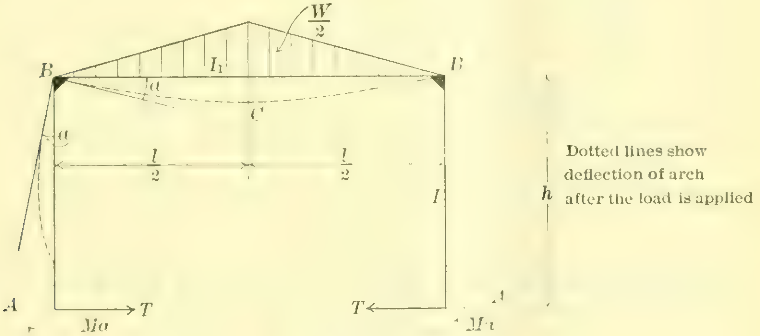


FIG. 13.

To find the unknown value, T, we have to consider that the inclination of the column at B with the vertical must be equal to the inclination of the slab with the horizontal line at B, and that, by a well-known rule of mechanics, the change of angle between tangents of two points of a beam equals $\frac{1}{E\,I}$ (area of diagram of moments).

The diagram of moments for the columns and slab is shown in Fig. 14. The area of the diagram for a column $= T\,h\,\frac{h}{2} - Ma\,h$,

or, as $Ma = \frac{T\,h}{3}$, the area $= \frac{T\,h^2}{6}$

$$\text{and } a = \frac{1}{E\,I} \times \frac{T\,h^2}{6} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The moment at $B = T\,h - Ma = \frac{2}{3}\,T\,h$.

Mr. Mensch.

It is easily found that the moment at any point between B and C

$$= \frac{W}{4} \times - \frac{W}{3} \frac{x^3}{l^2} - \frac{2}{3} T h \ldots\ldots (2)$$

The change of angle between the points, B and C, is again a, and equals $\frac{1}{E I_1}$ (area of diagram of moments between BC).

$$= \frac{1}{E I_1} \left(\frac{W}{4} \times \frac{1}{2} \times \frac{l^2}{4} - \frac{W}{3 l^2} \times \frac{1}{4} \times \frac{l^4}{16} - \frac{2}{3} T h \times \frac{l}{2} \right)$$

$$a = \frac{1}{E I_1} \left(\frac{5}{192} W l^2 - \frac{T h l}{3} \right) \ldots\ldots (3)$$

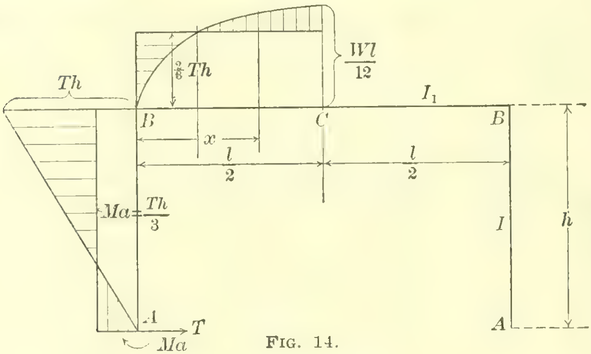


FIG. 14.

Combining Equations 1 and 3, $\frac{1}{E I} \times \frac{T h^2}{6} = \frac{1}{E I_1} \left(\frac{5}{192} W l^2 - \frac{Th}{3} l \right)$

$$\frac{1}{I} \frac{T h^2}{6} + \frac{1}{I_1} \frac{T h l}{3} = \frac{1}{I_1} \frac{5}{192} W l^2$$

$$\frac{T h l}{3 I_1} \left(1 + \frac{h}{l} \frac{I_1}{I} \times \frac{1}{2} \right) = \frac{1}{I_1} \frac{5}{192} W l^2$$

or

$$T h = \frac{5}{64} W l \frac{1}{1 + \frac{1}{2} n} \ldots\ldots (4)$$

or

$$Ma = \frac{5}{192} W l \frac{1}{\left(1 + \frac{1}{2} n\right)} \ldots\ldots (5)$$

or

$$M_B = \frac{5}{96} W l \frac{1}{\left(1 + \frac{1}{2} n\right)} = \frac{1}{19.2} W l \frac{1}{\left(1 + \frac{1}{2} n\right)} \ldots (6)$$

From Equation 2, $M_C = \frac{W}{4} \frac{l}{2} - \frac{W}{3 l^2} \times \frac{l^3}{8} - M_B = \frac{1}{32} W l \frac{\left(1 + \frac{4}{3} n\right)}{1 + \frac{1}{2} n} \ldots (7)$

These are practically the same equations as found for Case V, modified only by the value of n. It will be assumed that the floor in the former example is 9 in. thick, and that the columns are 24 in. in diameter. Mr. Mensch.

$$l = 20 \text{ ft.}$$

$$h = 12 \text{ ft.}$$

$$t = 9 \text{ in.}$$

$$I_1 = 240 \times \frac{9^3}{12} = 14\,580.$$

$$I = 24^4 \frac{\pi}{64} = 162\,000,$$

$$n = \frac{h}{l}\,\frac{I_1}{I} = \frac{12}{20} \times \frac{14\,580}{162\,000} = \frac{1}{18.5}.$$

Where columns are also on the top of the floors, n must be taken as one-half of the value thus found, or, in this case, $n = \frac{1}{37}$. n must be further reduced because the adjacent floor slab increases the restraining influence, and a value for n of about $\frac{1}{40}$ is probably correct for this case. The smallest column which could be used in this case to carry the load of 150 000 lb. would be 15 in. in diameter, or $I = 25\,000$, and $n = \frac{1}{2.86}$. From Equations 6 and 7 we obtain

$$\begin{array}{lcccccc}
\text{for } n = & 1 & \frac{1}{2} & \frac{1}{4} & \frac{1}{10} & \frac{1}{40} & \frac{1}{x} \\[6pt]
M_B = W\,l \times & \frac{1}{28.6} & \frac{1}{24} & \frac{1}{21.6} & \frac{1}{20.1} & \frac{1}{19.7} & \frac{1}{19.2} \\[6pt]
M_C = W\,l \times & \frac{1}{20.6} & \frac{1}{24.1} & \frac{1}{27.1} & \frac{1}{29.7} & \frac{1}{31.4} & \frac{1}{32}
\end{array}$$

In most cases n is a very small value, and the moments of

$$M_B = \frac{W\,l}{19.2}, \text{ and } M_C = \frac{W\,l}{32},$$

may be adopted for the design of flat floor slabs; the larger the cap the greater will be the width of the floor slab which takes the greatest portion of the entire bending moment, and the more certain is it that the arch action actually takes place as assumed herein.

A parabolic distribution of the entire bending moment over the width of the floor slab will give working stresses which are on the safe side, especially as we neglect the favorable influence of stresses acting in two directions at right angles to each other (wherein Poisson's ratio enters) and because we neglect the fact that the actual span is somewhat smaller than the distance from center to center of columns, but much greater than assumed by the author.

Mr. Mensch.

The bending moment of $\frac{W\,l}{19.2}$ (W being the total live load for inside panels and the total live and dead load for outside panels) is not taken up by the columns alone, but is divided between the columns and the floor slabs of the adjacent unloaded panels, and may be found as follows:

$$M_B \text{ for column } = \frac{M_B}{n+1}$$

$$M_B \text{ for adjacent slab } = M_B \frac{n}{n+1},$$

where $n = \frac{h}{l}\,\frac{I_1}{I}$, without any reduction. The portion of the moment taken by the columns must again be divided in proportion to their respective moments of inertia between the lower and upper columns. In this example, $\frac{W\,l}{19.2} = 104\,000$ ft-lb.

Assuming that one-half is taken by the lower columns and one-half by the upper columns, each column must be calculated for a bending moment of 50 200 ft-lb., which will cause a maximum compression in the 24-in. columns of at least 400 lb. per sq. in., which stresses, the writer is sorry to state, are generally neglected, in building flat floor constructions, even by the most successful firms. The fact is that, although the columns are under high compressive stresses in the lower stories of buildings, under test loads, cracks in columns, where noticed before they were detected in the slabs, prove conclusively that this arch action exists, and that the columns must be calculated for bending.

There is still another proof that this arch action exists. The deflection of a slab floor can be calculated by introducing Equation 4 into Equation 2 and integrating twice; then, for $x = \frac{l}{2}$ we obtain the deflection in the center of a side $= \frac{7}{3\,840} \times \frac{W l^3}{E I_1} \times \frac{1+n}{1+\frac{1}{2}n}$.

Substituting for $I = l\,\frac{t^3}{12}$ and neglecting n, the deflection $= \frac{1}{45.7}$

$$\times \frac{W l^2}{E\,t^3} \qquad (8)$$

This result is in inches when l and t are in inches.

It can also be shown that a strip forming the center of a square which is subject to a moment of $\frac{W\,l}{36.4}$ in the center and $\frac{W\,l}{38.4}$ at its ends

must deflect one-half the amount given in Equation 8, and we obtain the maximum deflection in the center of the square as $= \frac{1}{30.5} \frac{W l^2}{E t^3}$. (9) Mr. Mensch.

Introducing for E the value, 1 500 000, the deflections thus calculated are borne out by tests more closely than for any T-beam test which has come to the writer's notice.

To sum up: A flat floor slab should be calculated for a negative bending moment over the support of $\frac{W l^2}{15.3}$ ....(10)

per linear foot; and for a negative bending moment in the center of the sides of $\frac{W l^2}{38.4}$ ....(11)

It should be calculated for a positive moment of $\frac{W l^2}{25.6}$ ....(12)

per linear foot near the side of the square; and for a moment of $\frac{W l^2}{64}$.(13)

per linear foot near the center of the square, provided the columns are calculated for a moment of $\frac{W l}{19.2}$.

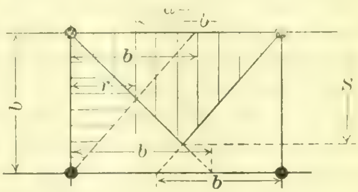


FIG. 15.

It remains yet to be shown how flat floor slabs are to be calculated when the columns are arranged in the corners of rectangles instead of squares, as shown in Fig. 15.

Where $\frac{a}{b}$ is less than 1.5, it is the writer's practice to calculate the long span for a width of $2s$, and to assume $W = w \times a \times 2s$, and to calculate the short span for the width, $2r$, and the corresponding $W = w \times b \times 2r$.

For a greater ratio of a to b, it is best to calculate the long span for the total moments of $\frac{w l^2}{12}$ and $\frac{w l^2}{24}$, over the supports and in the center of the span, when $W = w \times a \times b$, and to calculate the short span as before for $W = w \times b \times 2r$.

As in all other continuous girder constructions, unequal settlements of the supports will produce here a great change in the stresses, and conservative designers will modify the moments in Equations 10 to 13 according to their judgment.

A great change in the distribution of the moments is also caused by drops in the floors, which come now more and more in use, just at the columns, generally $\frac{4}{10}$ l square, and $\frac{1}{2}$ to $\frac{3}{4}$ t thick. The in-

Mr. Mensch. crease of stiffness around the columns increases the negative moments to a maximum of about $\frac{Wl}{15}$, and decreases the positive moments in the center to about $\frac{Wl}{60}$, instead of $\frac{Wl}{19.2}$ and $\frac{Wl}{32}$, as found before.

The flat slab floor with drop is a great improvement over a floor with uniform thickness, because the shearing stresses at the columns are decreased considerably thereby. The actual shear at the periphery of the cap is much larger than statics alone would lead us to adopt. The negative moment at the columns can be replaced by vertical forces acting in the opposite direction around the periphery of the cap, which new forces increase the shear on the loaded side and decrease it on the unloaded side of the columns. Assuming the side of the square cap to be $\frac{2}{10} l$, the new shear on one side of the square $= \frac{Wl}{15} + \frac{2}{10} l = \frac{W}{3}$, the shear from stations being $\frac{W}{4}$.

Mr. Turner. C. A. P. TURNER, M. AM. SOC. C. E. (by letter).—The writer feels moved to contribute to the discussion of this subject, in which he has been greatly interested for the last sixteen years, because, in the course of his experience, acquired in the design and construction of from 1 000 to 2 000 structures of this type, varying in span from less than 12 ft. up to 50 ft. from center to center of columns, and built to carry loads from 50 lb. up to between 1 and 2 tons per sq. ft., he has become somewhat conversant with the commercial requirements of a working theory for such flat slab floors. These requirements may be stated in brief to be two:

First, it is necessary to know with certainty what test load can be guaranteed to be carried by the proposed slab without injury, and second, what limiting deflection can be guaranteed under test load. Such guaranty, both as to carrying capacity and deflection, is a common demand on the part of those furnishing the money for financing the construction of a proposed building or structure; and the conservative business man who advances the money, as the writer has found by experience, would usually like a bond, which may amount to anywhere from \$5 000 to \$100 000, to assure him that the structure when completed will come up to the guaranty.

Consequently, the responsible engineer must have an absolute knowledge of the deflection which his design will exhibit under load, and a feasible and practical method of determining its strength, such as will include a reliable estimate within narrow limits of the stresses that actually will occur in the steel under given loads.

In case a working theory can be developed along rational lines which will include these particulars, its accuracy as an application of

Mr. Turner.

the general theory of elastic materials can be readily checked by measurements on the behavior of the slab, to ascertain first, whether its actual deflections coincide with theoretically computed deflections, and second, whether the stresses occurring in the steel and in the concrete in each and every part of the slab agree with the results of mathematical theory. These checks and cross-checks would be such as would render the accuracy of the theory unassailable, or else would stamp it as a mere theoretical absurdity which in some of its fundamental assumptions does not correspond to and take correct account of the controlling factors of the design. Such a complete theory, further, must account for the fact that a thick slab will sustain around the cap higher shearing stresses per unit of cross-section than a thin slab, and must indicate what those stresses should be.

In the experience above referred to, as already stated, the writer has been called on to design structures for loads varying from 50 lb. to between 1 and 2 tons per sq. ft. over full areas, and it has been necessary for him to know with a high degree of certainty what the deportment of slabs would be for short spans, and for long spans, for the limiting practical thickness, and for greater thicknesses, and to investigate carefully the maximum allowable percentage of steel for these various thicknesses in order that its resistance might be properly developed by the concrete and so determine a limit beyond which the addition of a greater percentage of steel is merely a waste of materials.

In the examination of this paper, none of these essential commercial requirements seems to have been mentioned, and no evidence whatever is offered in the form of experimental determinations to show that the results arrived at have any foundation other than that of the mere algebraic deductions which the author has based on certain assumptions.

These assumptions and deductions by Mr. Nichols appear to involve the most unique combination of multifarious absurdities imaginable from either a logical, practical, or theoretical standpoint. At the very outset he assumes the illogical proposition that the mechanics of a slab and the mechanics of a beam are identically the same, and then, lest this assumption appear doubtful, he makes a remarkable assertion in lieu of any proof of his statement in the following words:

"With whatever industry the powers of higher mathematics and the mysteries of Grashof's formulas and Poisson's ratio may be invoked, they cannot justify a result for the maximum stress in the steel smaller than the limiting value determined in this paper."

The writer has frequently found that mathematical formulas were mysterious and incomprehensible when he has tried to understand them before thoroughly digesting the notation and interpretation of the symbols used in the formulas and the definitions of the elementary technical terms in the discussion.

Mr. Turner.

Now, in the case of Mr. Nichols, it would seem that the mysteries of Grashof are mysteries to him for this very reason, as he has apparently not mastered the notation and meaning of the symbols used by Grashof and other well-known writers on the mathematical theory of elasticity. In this the writer refers to Mr. Nichols' abuse of the greatly over-worked term, "moment," which is used to apply to so many different things. The kind of moment must be specifically understood, and defined, if it is intended to place different moments in an equation on a basis of equality or inequality. Eddy* clearly defines the external moment of forces acting on a slab or beam as apparent moments. Mr. Nichols designates the apparent moment as M. Eddy specifically defines true moment as the unit stress or summation of unit stresses, multiplied by their lever arm, which, in the case of a reinforced slab, would be the unit stress in the steel, multiplied by the area of the steel, multiplied by its effective lever arm. The form of a beam, which is narrow, limits the reinforcement to practically one-way reinforcement of no considerable width. Hence, in a beam, the apparent moment equals what Eddy would term the true moment. Or, this might be put in another way: The apparent moment equals the total effective internal moment, which in turn may be defined as equal to the true moment plus the moment of resistance of the equivalent lateral effects. By lateral effects the writer refers to the extent to which the stress in one system of reinforcement may offset or nullify that in another system of reinforcement by co-action or interaction between the two. Now, in a beam, due to its narrow width, the fact that all the bars run parallel to each other, these lateral effects reduce to zero. Hence for the beam, the apparent moment equals the true moment. In the slab, the apparent moment, M_x†, equals the effective internal moment M_I † which equals the true moment plus the summation of the lateral effects, and it is these lateral effects which Mr. Nichols inadvertently leaves out of consideration in his theory, thereby arriving at results differing from 100 to 200% from those which would be logically obtained by a proper consideration of the difference in the mechanics of the beam and the slab found in the forms which he has selected for discussion.

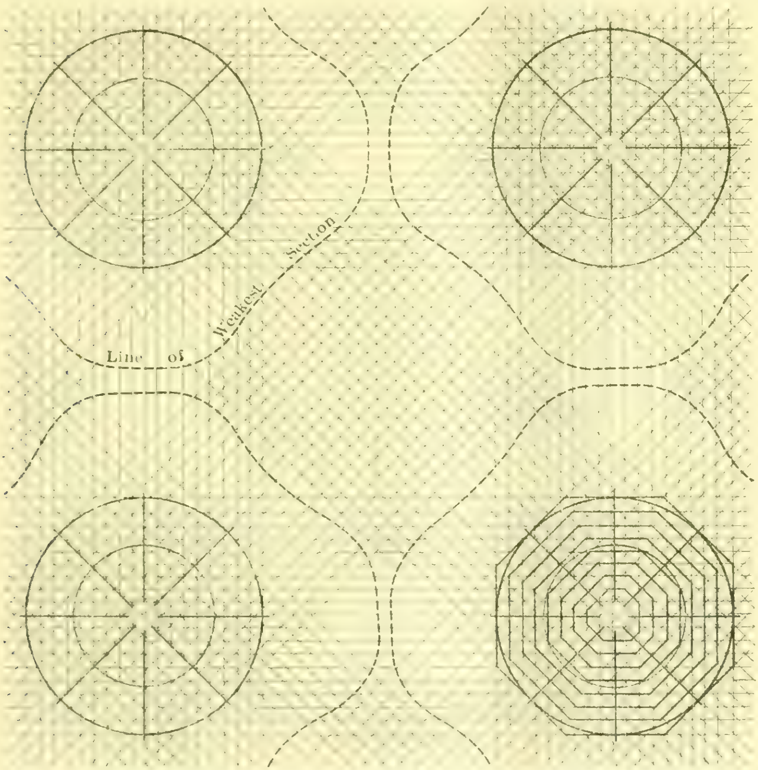
Perhaps the magnitude of this surprising error may be brought out better from consideration of the geometrical deformations than by what Mr. Nichols might term the mysteries of Poisson's ratio.

Fig. 16 is an ordinary plan view of the writer's standard construction in which the slab rods are at the bottom of the slab between the supports and at the top of the slab over the supports. Fig. 17 is a plan and sectional elevation of the slab, showing its deformation under uniform load somewhat exaggerated.

* "Flat Plate Theory of Reinforced Concrete Floor Slabs," 1913.

† Turner's notation, "Concrete-Steel Construction," p. 26.

When the load is applied, the slab deflects, and, by reason of its action as a circumferential cantilever, for wide areas about the column centers, there is a radial deformation at the section shown, which may be termed ΔR, which is an elongation at the top fiber and a shortening or compression at the lower fiber. Now, the deflection being relatively small, this difference in length of R, measured on the neutral Mr. Turner.



SLAB RODS ACTING AS CIRCUMFERENTIAL FRAMES
TO RESIST CIRCUMFERENTIAL DISTORTION

FIG. 16.

surface before and after bending, would be for approximate comparative purposes negligible. Hence it must be concluded from the necessary geometrical relations of the deformations that the total circumferential elongations on the upper surface are substantially $2 \pi \Delta R$, or, roughly, $6\frac{2}{7}$ times as great as the radial deformation.

Referring to Fig. 16, at the lower right corner, the formation of concentric octagonal polygons one within the other, has been accen-

Mr. Turner. tuated by shade lines, and it becomes evident that the deformation of the slab is resisted directly by the radial resistances offered by the materials and also by the circumferential stresses induced in this series of concentric polygons, thus providing two kinds of support by which, under the principles of least work, the load may be carried, whereas in either the simple or continuous beam there is only one kind of support.

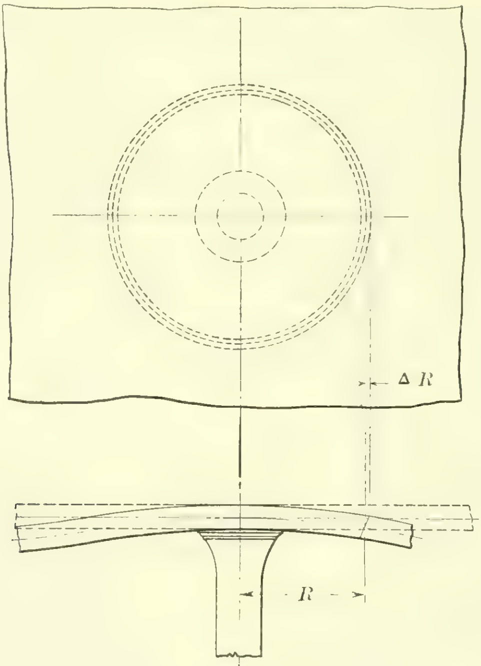


DIAGRAM ILLUSTRATING THE DEFORMATION OF A FLAT SLAB UNDER LOAD

FIG. 17.

The determination of the load which would be carried by these respective resistances would (in accordance with the principles of least work) be in proportion to the rigidities of the resisting parts. However, it is unnecessary, for the purposes of this discussion, to go into the complete quantitative analysis of the efficiency of these two systems which appear in the cantilever portion of the slab, as the object is attained by pointing out the existence of these two systems by which the load may travel to its support, which constitutes a part of the fundamental difference between slab theory and beam theory, a difference which has been totally overlooked by Mr. Nichols.

The analogous action of the diagonal belts near the center of the panel brings out still more clearly the difference between slab theory and beam theory (or its equivalent), as applied to this part of the structure. This difference may be treated perhaps better in a rough, general manner by pointing out the analogy between the simple Pratt truss and the beam of homogeneous material in the manner by which the flange stresses increase toward the center. In a Pratt truss, for instance, having end panels with parallel chords, flange stresses are piled up or accumulated toward the center, according to the following laws: Mr. Turner

The end chord stress is V_1 (tan. θ), the second panel is ($V_1 + V_2$) (tan. θ), the stress in the third panel is ($V_1 + V_2 + V_3$) (tan. θ), etc.

Now, if in place of having a single truss to carry the load, there are two trusses intersecting at 90°, forming diagonals between supports, as in a slab, and there is in addition the condition that the trusses are stayed laterally at the panel points by heavy compression members, to similar posts in the truss normal to the first, there results the condition that the top chord stresses cannot accumulate toward the center in accordance with the law just mentioned as the deformation in the direction of the line of the chord would cause a corresponding deformation in the lateral braces and hence there would be two paths by which the load could travel, one by ring-like compressions around the squares formed by the braces, and the other by direct stresses. If the bottom chords were also connected by a series of ties similar to the struts assumed at the panel points of the top chord, their action would likewise be similar in reducing the accumulation of bottom chord stresses, thus furnishing two systems for the load to travel to the support. In like manner, the stresses in the main line of reinforcement at the center of the slab may be reduced in amount by the neutralization of the stresses in one truss by direct interaction of the stresses in another truss normal to it. For such a system it becomes apparent that one could not have the same tensile stresses at the center, and the cross-section of metal, therefore, need not be as great as required by the beam theory.

In the slab having sufficiently wide belts of two-way reinforcement, combined with the concrete, there is a complete system of lateral struts and ties provided in the diagonal belts, without the addition of more material, and hence a consequent reduction in the stresses involved in the steel.

In referring to the wide belts, it may be observed that with reinforcement in two directions crossing each other at right angles, tensile stresses are provided for in all directions, as they may be readily resolved into components parallel to one system of rods or the other, and the continuous concrete forms a strut which performs the functions of the suggested braces in the diagonal trusses assumed above for purposes of illustration.

Mr. Turner.

A little consideration of these elementary geometrical relations will fully convince Mr. Nichols of the error of the treatment proposed by him. These actions and interactions between different belts of reinforcement have been treated in a highly scientific and exact manner by Dr. H. T. Eddy, in his recent work on the "Theory of the Flexure and Strength of Flat Concrete Floor Slabs," previously referred to.

This discussion would be incomplete did the writer not mention one of the many absurdities involved in Mr. Nichols' paper, from the practical standpoint; this is the remarkable assumption that any differences between the limiting stresses which Mr. Nichols has assumed must exist and those which actually occur in the practical building, must be due to the fact that a warehouse is never loaded to its capacity. To the man who has designed many such buildings and seen hundreds of them in use, such an assumption is a most interesting absurdity. In fact, the experienced constructor who takes pride in his work and guarantees it, never allows himself to entertain such a comfortable delusion. On the contrary, he is inclined to figure carefully on the story heights of the building which he is requested to construct for warehouse purposes, to determine whether there is room enough between the floor and the ceiling to store more than double the rated working capacity of common commodities throughout the floor. In all localities where building ordinances are not in force, the warehouseman who rents a structure for storage purposes naturally proposes to make it produce the greatest possible revenue, so that, if he takes a contract for storing so many hundred or thousand tons of sugar, his method of loading is to pile the material on the floor, commencing at the most distant point from the elevator and filling it up solid from floor to ceiling. If, in such a structure, the designer can calculate that it is possible to get in between the floor and the level of the ceiling, more than twice the rated capacity of the building, he is justified in suggesting either that these story heights be decreased or that the design working loads for the proposed building be increased. The writer makes this statement advisedly, for the reason that he has been called on to report, on more than one occasion, on the question of how much material could be stored in a given building without actual collapse. He has found, on investigation on more than a dozen warehouses, that loads of more than double the rated working capacity have been stored for from 3 to 4 months without permanent injury to the construction, and over the full area of the slab, or over a large number of adjacent panels; and accordingly, in the light of this experience, when an engineer suggests the possibility that such floors may never be overloaded, or loaded to their full capacity, he feels that the brilliant originator of such an idea should go out and visit a few ordinary warehouses and become somewhat familiar with commercial conditions before presenting so ludicrous a suggestion and one which is so likely to mislead the novice in design.

In the foregoing statement it should be borne in mind that the warehouses referred to as having been over-loaded were designed using a coefficient of bending of $\frac{WL}{50}$, which coefficient took into consideration the lateral effects of the four-way reinforcement. The unit stress used was 13 000 lb. per sq. in. for live load plus dead load. If the dead load is taken as one-third of the live load, and the live load is doubled, the working stress would be $1\frac{3}{4}$ times 13 000, or about 22 000 lb. per sq. in.—a very reasonable and moderate working stress for medium steel having a yield-point value of at least 38 000 lb. per sq. in. If Mr. Nichols' discussion is correct, and this coefficient should be $\frac{WL}{19}$ instead of $\frac{WL}{50}$, it becomes evident that, instead of having a working stress of 22 000 lb., it would be something like 55 000 lb., or an amount greatly exceeding the yield-point value of the metal, and that, accordingly, if Mr. Nichols' method of computation were correct, the structure could not have sustained such a load without permanent deformation of the steel. Mr. Turner.

Looking at Mr. Nichols' paper in the light of an attempt to apply the impossible beam theory to the flat slab, it presents a practical absurdity in the manner in which it has been applied. Mr. Nichols proposes, quite properly, in considering his clear span, to take out a portion of the diameter of the cap, thus reducing the clear span, L. Now, for a continuous beam—and it is to be understood that he proposes to treat a continuous slab by his theory—the moments for an indefinite number of spans are $\frac{WL}{12}$ at the support, and $\frac{WL}{24}$ at the center. Splicing the rods over the head rapidly increases the metal, and any provision for shear which is essential for practical safety increases the metal at, and in the vicinity of, the supports. Such increase in metal increases the cantilever effect, thereby changing even for a continuous beam the relative moments that would be true or apply to a beam of uniform section, at the central portion. Why, then, should we assume for such a combination that a uniform stress in all the metal throughout should limit us to a value less than the mean of the moments at the support and at the middle? The proof of this proposition does not seem at all clear to the writer, from anything which is brought out in the paper and, in fact, he is inclined to conclude that the results arrived at, even on beam theory, are due to a partial rather than a complete application of the principles of statics.

The various published tests of extensometer measurements on slab rods where four belts are used show that the stresses in the rods of the diagonal belts are smaller at the center of these belts than are those in the rods of the direct belts at the center of the span. If the

Mr. Turner. beam theory governed in the distribution of the load on the respective belts, the stress in the steel should evidently be the same at the center of the diagonal belt as at the center of a direct belt, for a uniform load, and, when actual measurement shows a difference between the stresses measured and the beam theory, if assumed to apply, of nearly or approximately 70%, this difference is a fair measure of the lateral action in the rods of the diagonal belt which is not to be accounted for by beam theory. This fact is brought out, not only in experiments carried on for the writer, but in those carried on by others.*

In considering these remarks the writer may add that while this criticism, though incomplete, may seem somewhat severe, it should be borne in mind that a complete and correct mathematical treatment of flat plate floors, from the theoretical standpoint, is a decidedly difficult matter. The writer has handled this problem successfully by a method of experimentally determined coefficients, which amounts to using the method of design by proportion utilized with such admirable results by trade guilds or associations of the Dark Ages in the production of monumental works in masonry and arches which stand unexcelled to-day. This method, however, is admittedly not as satisfactory as a complete rational analysis along conventional lines. Notwithstanding the fact that the writer has devoted more or less time for the past 16 years in attempting to develop such a theory, he has failed in doing so, and would probably be still at work on it had not the problem been solved satisfactorily by Dr. H. T. Eddy, Professor of Mathematics and Mechanics, Emeritus, of the University of Minnesota, and Dean of the Graduate School of Engineering of that institution. At the writer's request, Dr. Eddy has submitted a short discussion, in an endeavor to elucidate some of these simple relations which Mr. Nichols refers to vaguely as the mysteries of Grashof's formulas.

Mr. Godfrey. EDWARD GODFREY, M. AM. SOC. C. E. (by letter).—This paper is timely and important. In these days, when systems are springing up with rapid growth, based on nothing but tests that satisfy only the promoters of these systems, and builders who are anxious to put up structures at rock bottom prices, it is well to get at the base of things, and scrutinize the theoretical ground on which such systems purport to be based.

There was a time when theory did not bother the promoter. He considered his guaranty sufficient to hush all critics and to awe the boldest of them. Sundry wrecks have opened the eyes of the public and of engineers, and more or less research is being conducted to discover what is wrong.

In the early formulas for reinforced concrete beams, tension in the concrete was frankly used for its full value. The possibility of a crack just where the tension is the greatest did not seem to impress these

* *Proceedings*, National Assoc. of Cement Users, Vol. 7, 1911.

theorists. Now, instead of using the tensile value of the concrete, the neutral axis of the beam is simply raised, and the allowed compression in the concrete is increased—just another way of doing the same thing—for tests to locate the neutral axis do not find it to be much, if any, above the center of the depth of the concrete beam. The theorists place the neutral axis very high, especially in a T-beam, which, of course, is a great advantage to the commercial builder of reinforced concrete. The loads specified for buildings are usually greater than the buildings will receive, so that if proper designs are made on this basis not a great deal of harm need result. Engineers, however, in building structures for rolling loads, should look deeper into the subject, if they want to build permanently. Mr. Godfrey.

In flat slabs supported on posts, the tensile strength of the concrete plays a still greater part in static tests than it does in beams, because the tension acts in all directions. Besides this, when an interior bay is tested, the aid rendered by the surrounding idle bays is great. In casting about for a plausible theoretical excuse, it was found that the neutral axis could not be raised a notch higher, hence, Poisson's ratio was drafted into service. When metal is in tension in one direction, it is extended in that direction, and contracts in a direction normal thereto. If now stress is applied normal to the first, it will tend to reverse the contraction in that direction and reduce the extension in the other direction. On the theory that stress is proportional to extension or so-called strain, it is argued that the tension in one direction, diminishes the effect of the tension normal thereto. This is the basis of Poisson's ratio. It is purely theoretical.

The writer has never found an engineer who was willing to use it in a hollow sphere under internal pressure, the most perfect case imaginable; in fact, spherical bottom tanks instead of being made about half as thick as their tension would indicate, are commonly made twice as thick, a difference of about 400% from what this theory would sanction. So much for Poisson's ratio, and confidence in the same where the ratio is really applicable, if it has any application whatever in designing.

There are two experimental cases where Poisson's ratio might seem to have some meaning. These are doubtful, however. In a material that draws out like steel before ultimate failure, the ultimate strength is raised by stresses that prevent the "necking" of the specimen. This is exhibited in notched or grooved tests. This has nothing to do with the action of steel under stresses within the elastic limit. Glass, which is elastic up to failure, does not appear to exhibit this increased ultimate tensile strength, as will be shown later. The other case is where pressure is applied on a small area in the center of a broad flat stone or other similar substance. Much more pressure can be sustained than on a small cube, on account of the crowding of the material.

Mr. Godfrey.

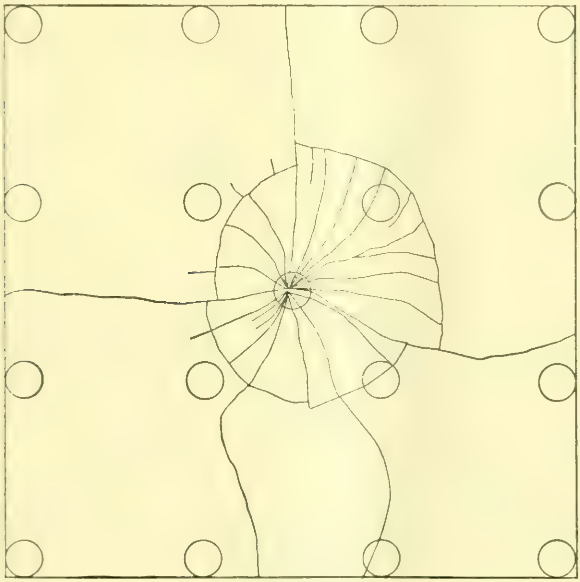
There is one place where Poisson's ratio has no application, and that is in the steel rods reinforcing a flat slab, the very place where it has been called in to bolster up false theory. The stress in steel rods reinforcing concrete can be only in the direction of the axis of the rods. It is astonishing what misapprehension exists regarding this subject. Some writers appear to think that Poisson's ratio is some mysterious thing by virtue of which a flat plate is supported by circular stresses, due to the dishing.

As stated by Mr. Nichols, the tests on flat slabs have been generally applied to single interior panels. Sometimes two or three interior panels are tested. There are no recorded tests of isolated panels with the load in the square enclosed by the columns, and none on exterior panels, except where the outer edge was supported by a girder on a wall. Furthermore, there are no tests of flat slab construction where load was placed on all panels across a building. This is, in fact, a critical loading. It is the criterion, which, if applied to the commercial systems, will show clearly their inadequacy. As the writer has pointed out,* a flat slab on rows of posts is no better than the same slab on parallel lines of girders, in fact, not as good. The tendency is for a fully loaded slab to take a cylindrical shape between two lines of posts, as it would between two lines of girders. Applying this criterion, the bending moment midway between columns is found to be $\frac{W L}{12}$, and on the line of column heads $\frac{W L}{24}$, the total being $\frac{W L}{8}$, as compared with Mr. Nichols' $\frac{W L}{10.7}$, assuming the support to be a rigid ring around the head of the column. His analysis shortens the span by reason of the assumption that the support is at this ring at the head of the column. This shortens the effective span to 0.87 L and would make the writer's moment 0.0946 $W L$, as compared with his 0.0935 $W L$, which is accounted for by the omission of the load on the head of the column. It is to be observed that this is the smallest possible moment to be resisted; in the combined sections, A, C, and B, Cases II to V appear to be smaller, but this is only because more systems of rods cross these sections. It is to be observed, also, that in these systems of rods the lapping must extend a sufficient distance beyond the section, C, and the curved line, A, to develop the full strength of the rods. It is further to be observed that this moment is several times as great as that found by analysts who wrongly use Poisson's ratio.

The writer recently made some tests in an investigation of the stresses in flat plates supported on posts. The material used was glass. This material was chosen because it is elastic to the point of failure and will not sag or bag under a load. Test No. 1 (Fig. 18) shows how

* *Engineering News*, February 29th, 1912, p. 404.

a central load in an interior panel acts. The glass was 24 in. square and about 0.09 in. thick. The sixteen circles represent wooden blocks, $1\frac{3}{8}$ in. in diameter, which acted as posts. The load was balanced on a similar block at the center. The sheet of glass was held down by blocks over the sixteen posts. A load of $124\frac{3}{8}$ lb. caused failure. Test No. 2 (Fig. 19) shows a similar piece of glass, similarly conditioned. On the three blocks *A*, *B*, and *C*, there was placed a total load of 137 lb.; when the glass broke, this sheet was not quite so thick. Evaluating the load to the same thickness as the other sheet, on the assumption that the strengths are as the square of the thickness, this load would Mr. Godfrey.



TEST NO.1

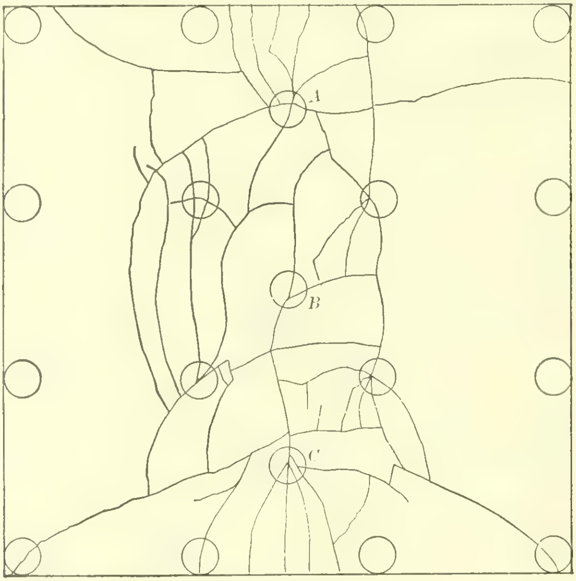
FIG. 18.

be $157\frac{1}{4}$ lb. Instead of being three times what the interior bay carried, this is only about $1\frac{1}{4}$ times as much. This indicates that, even in a brittle substance which does not sag and act in suspension, the supporting power of an interior bay is no indication of the supporting power of a row of bays.

The general trend of the breaks in Test No. 2 in a direction parallel to a line through *A B C* indicates clearly the tendency of the slab to assume a cylindrical shape under loads in a row of panels. If any load would cause dishing in the middle of a panel, it would be a center load; but this dishing effect is practically nullified by consecutive panel loads, so that the mainstay of some theorists is destroyed.

Mr. Godfrey.

It will be seen by the lines of the breaks in Test No. 1 that the glass broke in all directions in the center, where the load was applied and where the maximum intensity of stress evidently existed. Why did not conjugate stresses reduce the effect of stress at this point, as the theory of Poisson's ratio would indicate? Calculations of the modulus of rupture of some other tests of the series, which were smaller sheets supported on four posts, did not give results greater than for plain sheets in simple bending, in spite of the aid which conjugate stress is said to give.



TEST NO.2

Fig. 19.

An element of strength that is read into the slab itself (from the results of tests) is the bending resistance of the columns. The columns of a building are not calculated for bending, but, under a test load on the slab, they are only partly loaded, and can offer aid to the slab. This aid should not be counted on. It is dangerous to do so in a low structure or a bridge, where the full capacity of a column is apt to be reached.

There is no doubt of the fact that a large measure of the high showing of some tests on flat slabs of reinforced concrete is due to the tensile strength of the concrete. Tests on brittle material are therefore appropriate in an investigation of such flat slabs, especially where rolling loads or shocks are considered. Shocks in brittle material (con-

crete under tension) may cause rupture after months or years of use. What would happen in a proposed freight terminal, on flat slabs, when the shocks have cracked the concrete, and the steel receives its full stress, a long load down the middle of the slab causing it to act in bending as a cylinder, the calculated steel stress being about the elastic limit of the material? Mr. Godfrey.

There is nothing in the flat slab to commend it for rolling loads.

H. T. Eddy,* Esq. (by letter).—The fundamental erroneous assumption of this paper appears in its first sentence, which should state that statics imposes certain lower limits to the apparent applied forces that are to be resisted by the reinforcement in a flat slab floor. Mr. Eddy.

It is assumed, apparently unconsciously, by the author, that this statement is equivalent to that made in the paper, for the entire discussion in the paper hinges on the correctness of equating the apparent applied moments to the moments of resistance of the actual tensions in steel reinforcement, a method of procedure which is entirely correct for a beam, but wholly misleading and entirely incorrect for a slab, as will appear from the following discussion of true and apparent bending moments in a plate or slab reinforced in either of the various ways considered in the paper.

The source of the error appears in the author's statement regarding Grashof's formulas and Poisson's ratio.

Such a statement is entirely unwarranted, and not in accordance with the generally accepted principles of the theory of elasticity. There is nothing mysterious about Grashof's fundamental formulas. They simply express mathematically the experimental fact that, when a solid piece of elastic material is elongated under the action of an applied force, the material undergoes at the same time a lateral contraction, the amount of which is expressed by Poisson's ratio. That fact, the writer assumes, would not be denied by the author.

The fundamental equations of extensional stress and strain in thin flat plates and slabs, as given by Grashof,† and accepted by all authorities on the theory of elasticity, since then, may be written in the forms:

$$\left.\begin{aligned} f_{s_1} &= Ee_1 = p_1 - Kp_2 \\ f_{s_2} &= Ee_2 = p_2 - Kp_1 \\ \text{or,}\quad (1 - K^2)\,p_1 &= E\,(e_1 + Ke_2) \\ (1 - K^2)\,p_2 &= E\,(e_2 + Ke_1) \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

in which p_1 and p_2 are the external applied or apparent stresses per unit of area of cross-section of the plate or reinforcement of the slab which act parallel to the axes of x and y, respectively, if these latter lie

* Professor of Mathematics and Mechanics, Emeritus, College of Engineering, University of Minnesota.

† E. Grashof, "Theorie der Elasticität und Festigkeit," p. 352, 2d Edition, Berlin, 1878.

Mr. Eddy. in the neutral plane of the slab, and are parallel to the edge of the panel; and e_1 and e_2 are extensometer elongations of the plate or slab reinforcement per unit of length parallel to x and y, respectively, while f_{s_1} and f_{s_2} are the corresponding true stresses in the steel. E is Young's modulus and K is Poisson's ratio of lateral contraction to linear elongation. Any piece of material which is subjected to stress, and is of such shape that more than one of its dimensions is considerable, must have its stresses and strains considered with reference to lateral contraction. This is the case in plates and slabs, as it is not the case in rods and beams.

In the foregoing equations, Ee_1 and Ee_2 are the true stresses per square inch of section of reinforcement acting along the lines parallel to x and y, respectively, whatever p_1 and p_2 may be. These latter are the cause of true stresses, but are not themselves the values of the true stresses, as in case of rods, etc., where one dimension only is large. These equations show that the elongation, e_1, in the direction of x and y, is not dependent alone on the tension, p_1, applied in that direction, for it is diminished by any tension, $+ p_2$, acting along y, but is increased by any compression, $- p_2$, along y. It appears that any tension, $+ p_2$, assists the piece in resisting the elongation along x and makes it able to endure safely a larger applied stress, p_1, with the same degrees of safety, that is, with the same percentage of elongation or true stress; but it is equally true that any compression, $- p_2$, reduces the safe value of p_1 which may be applied to it. These principles are not in accordance with those which hold for rods and beams, the lateral dimensions of which are small compared with their lengths. This divergence between the true stresses, as shown by actual deformations, and the apparent applied stresses, is a fruitful source of error in the attempted computation of slabs. Equations (1) in their present form apply to simple extensional or compressive stresses and strains, but may be extended to apply to bending of slabs, in the following manner:

Take A as the cross-section of the reinforcement per unit of width of slab when the actual reinforcement is regarded as distributed in a thin sheet of uniform thickness, and let jd be the vertical distance from the center of the reinforcement to the center of the compressional resistance of the concrete regarded as a fraction, j, or, d, the distance from the center of the steel to the top of the slab. Then

$$A p_1 \; jd = \mathrm{m}_1 \text{ and } A p_2 \; jd = \mathrm{m}_2 \quad \ldots\ldots\ldots\ldots (2)$$

are the apparent bending moments of the applied apparent stresses, p_1 and p_2, per unit of width of slab, tending, when positive, to cause lines which, before bending, are straight and parallel to x and y, respectively, to become convex downward.

Again, $$Ee_1 \, Ajd = m_1 \text{ and } Ee_2 \, Ajd = m_2 \quad \ldots\ldots\ldots\ldots (3)$$

Mr. Eddy.

are the true bending moments of the actual resistance stresses in the reinforcement per unit of width of slab, as shown by the extensometer strains in the steel parallel to the axes of x and y, respectively.

Multiply Equations (1) through by Ajd and substitute the values given in Equations (2) and (3), from which is obtained the following relations between the true and apparent bending moments in the slab:

$$\left.\begin{aligned} m_1 &= \mathrm{m}_1 - K\mathrm{m}_2 \\ m_2 &= \mathrm{m}_2 - K\mathrm{m}_1 \\ (1 - K^2)\,\mathrm{m}_1 &= m_1 + Km_2 \\ (1 - K^2)\,\mathrm{m}_2 &= m_2 + Km_1 \end{aligned}\right\} \qquad (4)$$

These equations bring out in a striking manner the essential divergence of the correct theory of slab action from that of beam action in which latter case there are the well-known equations, $m_1 = \mathrm{m}_1$ and $m_2 = \mathrm{m}_2$, that is, the moment of the applied forces is equal to the moment of the internal resistance, which is not true of slabs.

All attempts to base the computation of bent slabs on beam action are necessarily erroneous, for it is wholly inapplicable and misleading. Deflections and stresses in slabs cannot be computed correctly by any form of simple or compound beam theory.

Equation (4) shows:

1st.—That at points where the apparent moments, m_1 and m_2, are of the same sign (as, for example, in the convex part of the slab near the columns and also near the center of the panel), the true bending moments, m_1 and m_2, which determine the true stresses in the reinforcement, are less than the apparent bending moments in which the latter have been ordinarily assumed (according to the beam theory) to determine these stresses.

2d.—That the compressive stresses in the concrete around the column cap are determined on the same principles, and are consequently reduced in accordance with the value of K by a considerable percentage below values corresponding to m_1 and m_2 of the beam theory.

3d.—That the points where m_1 and m_2 have different signs, as they have, for example, in the middle part of the space directly (not diagonally), between the column heads, the values of the true bending moments are larger than the apparent moments as found by the beam theory.

4th.—One of the results of this is the fact, which is also completely confirmed by extensometer tests as well as theoretically, that the greatest actual extensions and true unit stresses in the reinforcement of slabs, as ordinarily arranged, occur at the mid points of the reinforcing rods which run directly between the column heads parallel to the sides of the panel and do not occur in the diagonals, at the center of the panel where m_1 and m_2 have their greatest values. Further, with suitable laps, the true stresses in the reinforcement are not so large

Mr. Eddy. over the columns as at the points just indicated. Neither of these conclusions is in accordance with the beam theory, as implied in ordinary formulas adopted for practice.

5th.—Any requirement or statement as to the bending moments at any point of a slab must state which kind of bending moments is called for, the true bending moments or the apparent moments, with the understanding that the true bending moments only are to be used in determining cross-sections of steel. Any requirement seeking to proportion the cross-sections of steel to apparent stresses and moments is incorrect.

It is evident from Equations (1) and (4) that Poisson's ratio, K, plays an important rôle in the theory of flat slabs and plates. Few attempts have been made to determine K by directly measuring the amount of the lateral contraction accompanying the elongation of test specimens, and, were such measurements made, the relative dimensions of the cross-section of the specimen would need to be considered as affecting in a very complicated way the true value of K to be derived from observation. Reliable determinations of K usually depend on observations of Young's modulus of elasticity, E, and the shearing modulus of elasticity, F.

It is proven, in the general theory of the deformation of isotropic elastic solids, that all the elastic properties of any such solid are determined without excess or defect by its values of E and F, and that Poisson's ratio is a function of E and F expressed by the equation:*

$$K + 1 = \frac{1}{2} \frac{E}{F} \qquad \text{(5)}$$

There is evidence to show that, for concrete, K is approximately 0.1.† For steel, it is known that $K = 0.3$, nearly.

Now, it is evident that a horizontal slab of reinforced concrete, in which the reinforcement consists of rods, differs from one in which the reinforcement is considered to be a simple uniform sheet of metal, in this, that the former has much less shearing rigidity in resisting horizontal forces than the latter, for in it all stresses transmitted from one band or belt of rods to any other belt crossing it are transmitted through concrete only, as is not the case if the reinforcement consists of a continuous sheet. It is evident, therefore, that the value of K which must be used in applying the foregoing equations to reinforced concrete slabs must exceed 0.3, the value required in case the reinforcement is a sheet of steel.

It may be objected that the transmission of longitudinal stress from the rods of one belt laterally to those of any belt crossing it

*Merriman's "Mechanics of Materials," 10th Edition, 1911, Equation (181), p. 466.

†Turneaure and Maurer's "Reinforced Concrete Construction," 2d Edition, 1912, p. 272 *b*.

involves secondary stresses in the concrete which we are not justified in assuming it to be capable of resisting. However, such objection is untenable, as is evident from the phenomena exhibited in the flexure of reinforced concrete beams, which show that the concrete retains its shearing bond with the reinforcement and transmits horizontal shears as secondary stresses to the neutral surface and to the concrete in the zone of compression long after it has passed the limit of its tensile strength. Were it otherwise, reinforced concrete beams would be of no practical utility. Action of this kind likewise occurs in the reinforced concrete slab where the bond between the concrete and the belts of rods embedded in it bring them into co-action with each other in a manner like the co-action of the parts of a reinforced concrete beam. Mr. Eddy.

This analysis of the conditions affecting the value of K for a reinforced flat slab differs radically from assuming at random that because $K = 0.3$ for steel alone and $K = 0.1$ (possibly) for concrete alone, that therefore some intermediate value of K may be correct for these two materials combined in a slab. Such an assumption is merely a blind guess, and has no rational basis.

As already partly stated, the view here put forth is this: Since, in any homogeneous, isotropic, elastic material, the experimental values of E and F perfectly define all its elastic properties, and since we are evidently at liberty to assume our flat slab as sufficiently fine grained in its structure to act nearly like a slab constructed of some sort of homogeneous materials, it will be possible to determine certain mean values of E and F which will define its elastic properties. It is, moreover, evident that in a slab, where two kinds of elastic solids are combined as they are here, the mean value of F for the combination is affected much more by the concrete than is E, which latter may be taken as that applying to the steel alone, and, consequently, as unchanged by the combination. It is otherwise, however, with F, because the arrangement of the combination is such as to require the assumption of a value of F lying somewhere between that for steel and that for concrete. As the latter value is much less than the former, the mean value of F is smaller than for steel alone.

This reasoning and other independent theoretical and kinematical considerations have led to the same conclusion, namely, that the correct value of K for the slab is larger than 0.3.

Assuming $E = 30\,000\,000$, we may compute the corresponding values of K and F from Equation (5) as follows:

If $K = 0.1$, $F = 13\,600\,000$.
If $K = 0.3$, $F = 11\,600\,000$.
If $K = 0.5$, $F = 10\,000\,000$.

Mr. Eddy. If a perfectly complete and accurate mathematical theory of the flat slab were at our disposal, we might consider every experimental test of the deflection of such a slab, and every extensometer measurement of its reinforcing rods as an experiment for determining the numerical value of K, as deflections and extensions would then all be known functions of K. Having brought such a rational theory to a somewhat satisfactory degree of perfection, the writer finds that, in the light of all known tests of cantilever, flat slabs, of the standard mushroom type, with four-way reinforcement covering the entire slab area, the value that best satisfies all conditions is:

$$K = 0.5 \qquad (6)$$

It is possible that this value of the constant, K, for slabs may need some slight modifications hereafter, but for the present this may be regarded as substantially correct for such slabs. It may be found necessary to assume a somewhat different value for other forms of structures, as, for example, beam and girder construction. That, however, must be determined later. Moreover, it must be said that this value of K applies to tests of slabs from 2 to 4 months old, and under loads which have been applied to such relatively soft concrete as this for a period of usually not longer than 1 or 2 days, and of an intensity such as to cause a maximum stress in the steel of from 10 000 to 20 000 lb. per sq. in. Less loads on better cured concrete, or longer time under load, may possibly show some deviation from this value of K.

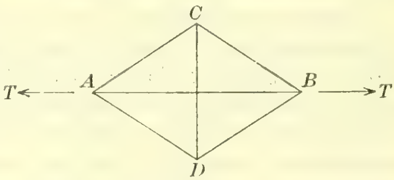


FIG. 20.

How important a factor K is in slab theory is evident on considering Equations (4) which show that in a square panel, uniformly loaded, the true moments, as shown by the elongations of the reinforcing rods at the center of the panel, and over the centers of the columns, are only one-half the corresponding apparent moments derived from considering the moments required to hold the applied forces in equilibrium, this being on the assumption, of course, that $K = 0.5$.

A further and somewhat more elementary consideration of the questions at issue may put the matter in clearer light and facilitate the discussion.

Let $A\ B\ C\ D$, Fig. 20, be any stiff diamond frame (which for the present will be assumed to be made of steel) such that the joints at the corners are of unknown stiffness. The sides, too, are of unknown inclination and cross-section. In addition, let $A\ B$ be a tension member of known cross-section, and $C\ B$ be a compression member, also of known cross-section.

If known tensions, T, were applied at the corners, A and B, it would be impossible, under the circumstances, to determine by the laws of statics alone what stress would occur in $A\ B$ or $C\ D$. So long as the relative dimensions, inclination, cross-sections, and other structural properties of the parts of the diamond frame are unknown or hidden, it is absolutely impossible by mere statics to find out how much of the applied forces, T, are resisted by the tie, $A\ B$, or the strut, $C\ D$, and any attempt to correlate these forces with the stresses on such a basis would be entirely without foundation. Mr. Eddy.

In default of any structural data respecting the diamond frame, the only recourse would be to experiment on the properties of the proposed arrangement. Now, this is precisely what occurs in the reinforced concrete slab. The known members, $A\ B$ and $C\ D$, represent parts of the reinforcement, and the diamond frame acts like the matrix of concrete in which they are embedded. The properties of the matrix in combination with the reinforcement are not readily amenable to analysis, and the mechanics of its action is largely hidden from view, but, whatever it may be, it is not difficult to discover the general nature of its action.

What this is, is evident from a careful consideration of what goes on in a simple concrete beam reinforced with steel rods near its lower surface. Though it is not permissible to consider direct tension in the concrete as an element of strength, it is not only permissible but necessary to consider the bond value of the shearing stresses in the concrete enclosing the rods, as well as the horizontal shears in the beam. These last, in fact, are absolutely essential to the action of the beam in order to transmit the tension in the steel at the bottom to a parallel position vertically above it where it can be neutralized and held in equilibrium by the compressions of the concrete in the upper part of the beam. However, such shears, vertical and horizontal, as are here admitted to exist, constitute a state of stress in the concrete in which indirect tensions and compressions exist on planes inclined to the planes of shear. It thus appears that, though direct tension may not be relied on as an element of strength in concrete, the same is not true of indirect tension, which is not only admissible but always necessary for beam action.

Now, in a slab, just such indirect tensions and compressions occur in the distribution of stresses laterally in the concrete as occur in the beam in distributing them vertically, and it is by means of them that horizontal stresses in one direction in the slab are brought into coaction laterally with stresses in other horizontal directions without producing what would otherwise be their full effect on the steel. In other words, the matrix represented by the diamond frame, $A\ B\ C\ D$, acts in such a way as to resist part of the applied force, T, without itself undergoing anything except permissible indirect stresses such as occur

Mr. Eddy. in beam action. In a way, the horizontal dimensions of a slab play a part to reduce both direct and indirect stresses in a manner analogous to the reduction of such stresses in a beam by reason of its vertical dimensions.

Here is an element of strength and resistance in the slab heretofore entirely disregarded, but one which must be considered just as unavoidably as in reinforced beams. If it cannot be neglected in one case it cannot in the other, in any rational analysis of the factors that must be taken account of in the behavior of slabs when considering their strength and resistance.

The final effect of this analysis is to show that, although direct tension in concrete is not admissible, and not to be counted on as an element of strength, the unavoidable indirect tensions in the concrete are such as to play a most important part in resisting the applied forces; and that, consequently, the reinforcement is called on to resist only part of the tension which is caused by the applied forces. The reinforcement may be regarded as in a sense protected by the concrete from much of the tension it would be compelled to sustain were the concrete not thus co-acting with it. The divergence of results reached by Mr. Nichols and the writer is largely due to this consideration.

The conclusions arrived at in this discussion which have not been heretofore explicitly summarized may be stated as follows:

1st.—The attempt to derive the stresses in multiple-way reinforcement of a slab from the equations of statics is futile, and cannot possibly lead to correct results.

2d.—This is not merely because the applied forces in a given direction are only partly borne by reinforcement in that direction and partly by all the lateral reinforcement there may be in other directions (even by that at right angles), but because the bond of the concrete and steel necessarily calls indirect stresses into action in the concrete, which help resist the applied forces, such indirect stresses being of precisely the same kind as are always found to act in reinforced concrete beams.

3d.—This method of co-action of steel and concrete gives no warrant whatever for the assumption that it is ever safe or proper to rely on unreinforced concrete for resistance to direct tension.

4th.—In case of one-way reinforcement in the direction of the applied forces, the concrete is an element of strength, by reason of its compressive resistance at right angles to this direction, even though the concrete may be so full of hair cracks at right angles to the applied tensions as to afford practically no resistance to them.

5th.—Any area of concrete not situated so as to be tributary to reinforcement, so that the steel can co-act efficiently with it, cannot be subjected to tensile stresses beyond certain limiting intensities without cracking.

6th.—Every safe slab must have reinforcement on its face, at or near where tensile forces act, in order to co-act with the concrete in resisting them without prohibitive direct tensions in the concrete. Mr. Eddy.

An instance of this co-action too frequently overlooked is that of the steel over the column heads, which, if sufficiently stiff, prevent prohibitive tensions in the concrete across the top of the slab over the side belts of the panels, even at the considerable distances of the mid-span.

7th.—Although, in its total effect on reinforced concrete, the action of indirect stresses, as just developed, separates the resistance to the applied tension into two parts, one resisted by the reinforcement, and the other by the concrete, it requires the presence of the steel in order to develop any tensile resistance in the concrete, and when the steel is not present, no direct tensile resistance whatever is to be ascribed to the concrete. This is believed to be in entire accordance with good practice, and with the consensus of opinion among responsible engineers, as well as in accordance with most city ordinances on the subject, and is a principle that should be adhered to.

A. W. Buel, M. Am. Soc. C. E.—In the course of preparing a report on two buildings of the Turner "mushroom" type, then under construction, the speaker obtained from the Library of this Society, a search on this subject, brought down to October 17th, 1911. This search contained twenty-six references, of which about ten required careful consideration and comparison. Mr. Buel.

The formulas and methods which had then been proposed as a basis for the design of flat slab floors gave results varying by as much as 300%, as illustrated by Table 1, which is taken from an article* by Mr. Louis F. Brayton.

TABLE 1.

No.	Method.	Thickness of slab, in inches.	Steel per panel, in pounds.
1	Cantilever	8	2 189
2	Turneaure and Maurer	12	1 931
3	Grashof	8	784
4	Mensch	8	2 120
5	Turner	8	549
6	McMillan	8	1 084
7	Brayton	8½	1 900

These methods, with the exception of Mr. Turner's, were not based on experiments of any consequence. In developing and checking his empirical method, Mr. Turner has made a considerable number of tests and experiments, but they are not entirely satisfactory or conclusive, because they are mostly confined to the loading of single bays, and because deformations or strains were not measured. They were suf-

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Mr. Buel. ficient, however, to show that something must have been neglected or erroneous data used in developing such formulas or methods as Nos. 1, 2, 4, and 7 of Table 1.

Mr. Arthur R. Lord has published* the results of his test of the slabs in the Deere and Webber Building, Minneapolis. Eight panels were loaded, and deformations were measured at twenty different points for the steel and about the same for the concrete.

Although neither Mr. Lord nor Professor Arthur N. Talbot, M. Am. Soc. C. E., consider the data of this test sufficiently comprehensive to form the basis of a complete theory, they do give some valuable indications, and incidentally tend to confirm the empirical method of Mr. Turner.

The author's results seem to be in substantial agreement with Methods Nos. 1, 2, 4, and 7 of Table 1, but they do not agree with the tests. It is hardly conceivable that the author could have been familiar with Mr. Lord's tests when he wrote the paper. That the presentation of formulas or analyses of this kind should include a comparison with the best available experimental data hardly needs to be said, but the paper discloses no reference to any tests at all. The author's reasoning seems to be deductive, which, since the time of Lord Francis Bacon, has not been in favor for scientific investigations.

The amount of reduction in stresses due to arch and slab action in the Deere and Webber Building test was observed to be large, and, until this can be included in formulas, with at least approximate accuracy, it is little better than a waste of time to discuss slab theories. If Professor Eddy has succeeded in doing this, and from his past work we may be encouraged to look to him for results, slab design may be reduced to a rational basis, but, until this has been done, the best method to follow is that of empirical proportions from experiments, being careful to keep the variations from test slab dimensions within very narrow limits.

A little study of the comparative table of methods and a cursory comparison with the Deere and Webber test data would seem sufficiently convincing that the problem is by no means so simple as the author's statements imply. In fact, it is so complex that no one has yet been able to present a rational basis for design of flat slabs, unless Professor Eddy has succeeded in doing so in his recent work. Turneaure and Maurer's method (No. 2 of Table 1) was based almost entirely on Professor Eddy's previous work, with the value of Poisson's ratio assumed at 0.1. It now appears that Professor Eddy proposes to use a much larger value for this ratio as a result of more recent experiments. Turneaure and Maurer's method is at least 300% in error, according to the tests which have been made.

* First in *Engineering News*, December 22d, 1910, and recently reprinted in *Bulletin No. 64*, University of Illinois, Engineering Experiment Station.

The speaker understood the author to say that theory is an explanation of facts, and that he liked to have his facts explained. The speaker has been unable to find a single fact in the paper, nor even an explanation of facts. It seems to be a paper of explanations, not only without facts, but contradicted by facts. The designers and builders of reinforced concrete structures have been waiting years for experimental facts on this slab question. We are beginning to get them, but we need at least twenty more such tests as that of the Deere and Webber Building before we will have a sound basis for a rational slab theory. Mr. Buel.

Should the discussion of this paper result in diverting some energy from theorizing toward the making of much needed scientific tests, the effort and space may not have been used in vain.

E. G. Walker, Jun. Am. Soc. C. E. (by letter).—The author's method of ascertaining a lower limit for the maximum stress in the steel of a reinforced concrete slab is of considerable interest. His assumption of absence of shear along the faces, *D, B, E,* and *C,* of the quarter slab (Fig. 1) seems to be quite justified in the case with which he deals; but, in practice, the use of a continuous slab supported on flare-topped columns is less general than the type of construction in which the floor panels are carried on secondary and main beams, which latter are supported by columns at intervals. In such a case, where the panel may be supported on four sides (Fig. 21), it may be assumed, using the author's reasoning, that there is no shear on the edges, *B* and *C,* of the quarter-panel. With reinforcement running parallel to both axes of the slab, and therefore supporting the slab along both edges, *D* and *A* (but principally along *D*), there must be shear on these two edges. Mr. Walker.

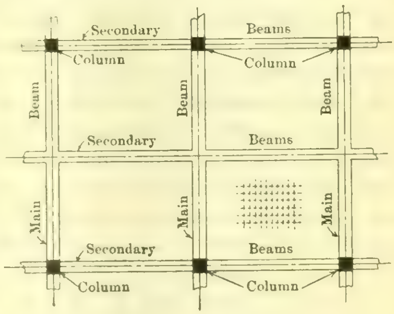


Fig. 21.

The writer would use the principles of Grashof's formula, or some equivalent method, in order to determine the relative values of these two shears, but would like to learn what the author's treatment would be in this case. The *raison d'être* of the paper is to ascertain a limiting value for the maximum stresses in the reinforcement, without the use of the more complicated and not wholly satisfactory assumptions of the slab formulas, but, for the moment, the writer does not see how, without their use, the author's method is to be applied to such cases as the one mentioned.

Mr. Crehore. WILLIAM W. CREHORE, M. AM. SOC. C. E.—In the opinion of the speaker, the observed differences between the author's beam theory and the actual results obtained in practice are due more to the cantilever action of the construction over the supporting columns than to tension in the concrete or to anything else.

The discussion of Mr. Nichols' very thoughtful paper seems to center about the method he uses in determining the statical limitation of the steel reinforcement in the floor slab—the point being raised by Mr. Turner that the so-called beam theory is not applicable to the calculation of a flat slab floor. It seems to the speaker that Mr. Nichols' answer to this objection is only partly effective, namely, that the direction of the stresses in the floor do not concern him, as he is dealing merely with the steel rod itself. It is quite true, and perfectly evident, that the stresses affecting the rod in the concrete can act only in one direction, that is, in the line of its length; but it is equally true that, in the slab floor, these stresses are partly relieved by the work of the rods lying in the other direction, and that this relief is not uniform throughout the whole length of the rod, nor anything like uniform, which means simply that each individual rod will be loaded in a manner peculiar to its position, and will not receive a uniform load throughout its full length, although the floor slab itself be uniformly loaded. At this point the advocates of the two theories part company, but that should not prevent the slab theorists from realizing that each rod by itself must act the part of a beam, in so far as it acts at all, nor the beam theorists from recognizing that the load on the slab is bound to get to the supports by the shortest possible road it can take, regardless of the location of the rods.

Without attempting to decide between the respective merits of these two theories of computation, why should we not apply the beam theory as nearly in accordance with the assumptions of the case as it is possible to apply it, for the sake of giving this theory a fair test? The author seems to have stopped short of the complete application of the beam theory by not having taken into account the bending moments over the points of support. He assumes, and has just confirmed the assumption, that his hypothetical floor panel is fully loaded and that the load extends uniformly in all directions over the adjoining panels. Under such an assumption, a strict application of the beam theory requires a consideration of the moments developed over the points of support, that is, over the columns. This fact the author has not recognized. It is, however, vital to the assumptions made in this case; and, even if the adjacent floor panels were not loaded, it would still be necessary to take into account the moment over the supports due to their dead load, because of the continuous and homogeneous nature of the construction of the floor. This end moment or pier moment, in a girder with fixed ends (or the continuous girder, to which

Mr. Crehore.

this case is analogous) is two-thirds as great as the moment developed at the center of an equal span having free ends, but, as it acts in the opposite direction, tending to hold up the central portion of the span, it should be deducted from the total moment due to a girder with free ends, such as the author has assumed when he writes $M = R_1 a$ as the bending moment due to all the external forces.

To recall a few elementary principles: Let the span, L, in Fig. 22, be one of the units of several equal spans, all uniformly loaded throughout with the unit load, w, per linear foot; and assume a beam of any material to rest continuously over the several supports so that the span in the figure is intermediate between loaded spans or panels on either side. Then the deformation of the beam in such a case would be concave downward for a distance from the support equal to about one-quarter of the span (actually 0.21133 of the span) and concave upward in the center portion of the span. The effect of the reverse moments due to the fixed ends or cantilever action over the supports reaches out from the supports to these points of contrary flexure, and the actual resulting moment at the center is precisely the same as would be that of a span with free ends inserted between these points of contrary flexure. This is true for any series of equal spans and for any load within the elastic limit of the material, so long as the load is uniform throughout all the continuous spans.

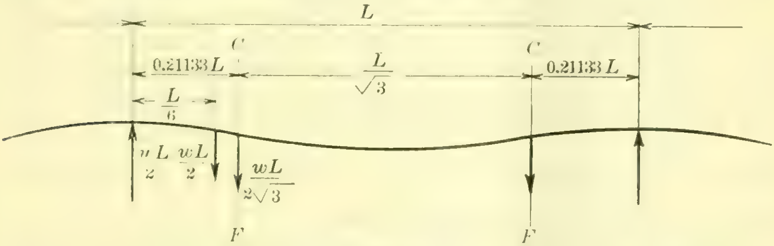


FIG. 22.

The moment over the support due to the load, wL, is $\frac{wL^2}{12}$, and the moment at the center of the span is $\frac{wL^2}{8} - \frac{wL^2}{12} = \frac{wL^2}{24}$. Theoretically, then, under the conditions assumed, the greatest moment is to be found over the support, and is twice as great as the resulting moment at the center; but, as points of maximum moment are also points of no shear, we do not find the greatest shear at the edge of the supporting column, where the author has assumed it to be, by his method of analysis. The greatest shearing force is to be found at a point where there is no moment, and in the present case such a point is in the plane, CF, of Fig. 22, where the curvature of the beam changes. At the point of contrary flexure in the plane, CF, the central portion

Mr. Crehore.

of the spans hangs, therefore, just like a loaded span with free ends supported on the tip of a cantilever arm, which in reality the portion of the beam between CF and the support is.

Now, the length of the span between the two planes, CF, is known to be $\frac{L}{\sqrt{3}}$, and consequently the load hanging at the end of the cantilever arm in the plane, CF, is $\frac{wL}{2\sqrt{3}}$. For convenience, writing $m = 0.21133\ L$, which is the distance from CF to the nearest support, we have, for the distance from the center of the support to the center of gravity of all the loads on the half span,

$$x = \frac{\frac{wmL}{2\sqrt{3}} + \frac{wm^2}{2}}{\frac{wL}{2\sqrt{3}} + wm} = \frac{mL + m^2\sqrt{3}}{L + 2\,m\sqrt{3}},$$

which, after substituting for m its value, gives $x = \frac{L}{6}$.

It is evident, therefore, that the couple to be resisted by the internal forces of the beam is exactly equivalent to that developed by assuming the half load to be concentrated at a point one-sixth of the span distant from the support, rather than at the quarter point (one-fourth of the span distant from the support), as has been done by the author. The latter would be correct for a span with free ends, but is incorrect for a span continuous over two or more supports. It will be noted, further, that the half load multiplied by the arm of this couple gives the moment, $\frac{wL^2}{12}$, which is known to be the maximum moment in the continuous-girder span uniformly loaded.

The application of this analysis to the case presented by the author is that the distance, a, of Fig. 2, between the forces, R_1 and R_2, forming the external load couple, should have been determined by treating the load of the quarter panel as if divided into two portions, which may be called the suspended and cantilever portions, respectively. If R_2 be located at the center of gravity of the quarter-column area, instead of at the center of gravity of the quadrant (as by the author's method), then the suspended portion of the panel's load should be assumed to be concentrated at a point situated 0.21133 of the diagonal distance between the centers of bearing. The author's distance, a, is not exactly the length of the quarter span between bearings, but is the definitely computed distance between the center of end shearing forces and the center of gravity of the quarter panel with the column area deducted. By the continuous-girder method, the arm, a, should be measured from the center of gravity of the quarter-column area

to the center of gravity of the suspended portion of the load and the cantilever portion of the load combined. Mr. Crehore.

If S, of Fig. 23, denotes the diagonal span between the centers of bearing, R_2 and R_2, and if m is 0.21133 of the diagonal span, S, then the suspended area of the panel is $DABCFE$, or the square, $OABC$, with the square, $ODEF$, deducted, and should be assumed to be con-

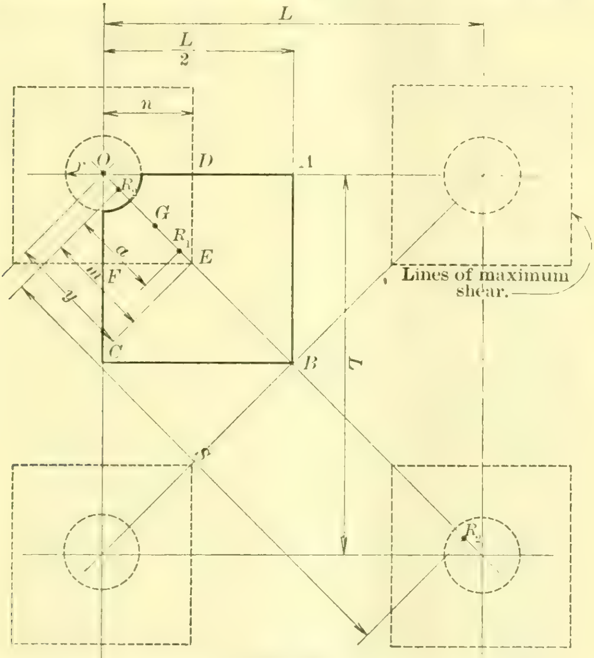


FIG. 23.

centrated at E. The cantilever area is the square, $ODEF$, with the quarter-column area deducted, and should be assumed to be concentrated at its center of gravity, G. To shorten the operation, it will be convenient to let

$$y = m + \frac{4\,r\sqrt{2}}{3\,\pi}$$

the distance from the point, E, to the center of the column, in which expression r is the radius of the column. We then find the arm,

$$a = \frac{3\,L^2\,y - 3\,y^3 - 4\,r^3\sqrt{2}}{3\,L^2 - 3\,\pi\,r^2} - \frac{4\,r\sqrt{2}}{3\,\pi}.$$

and the total moment of the couple due to R_1 and R_2 is

$$M = R_1\,a = w\left(\frac{L^2\,y}{4} - \frac{y^3}{4} - \frac{r\,L^2\sqrt{2}}{3\,\pi}\right).$$

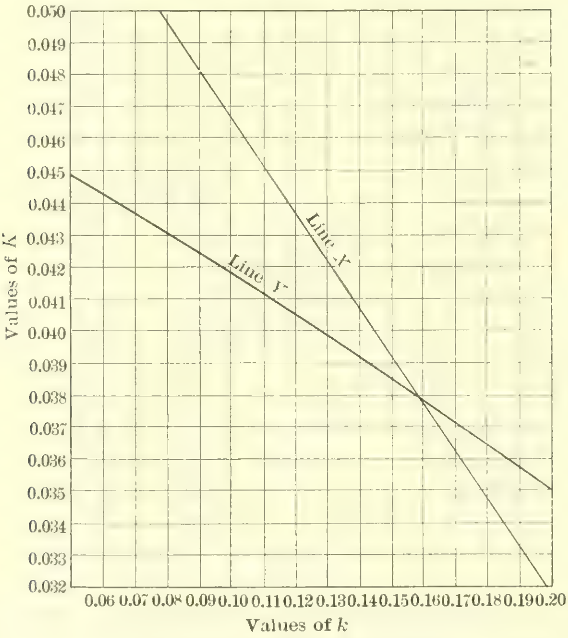
Mr. Crehore.

R_1 and R_2 being each the same as by the author's method, namely, $w\left(\frac{L^2}{4} - \frac{\pi r^2}{4}\right)$. Substituting $y = n\sqrt{2}$, we have

$$M = w\left(\frac{L^2 n}{4} - \frac{n^3}{2} - \frac{rL^2}{3\pi}\right)\sqrt{2},$$

from which, if $r = kL$, we obtain

$$M = w\left(\frac{L^2 n}{4} - \frac{n^3}{2} - \frac{kL^3}{3\pi}\right)\sqrt{2}.$$



Line X is reproduced from author's diagram, Fig. 3
Line Y is speaker's representation of values for K and k.

Fig. 24.

Resolving this into the component moments acting parallel to the sides of the loaded panel, as does the author, we have for one of these moments, after putting for n its value, $(0.211 + 0.245k)\ L$,

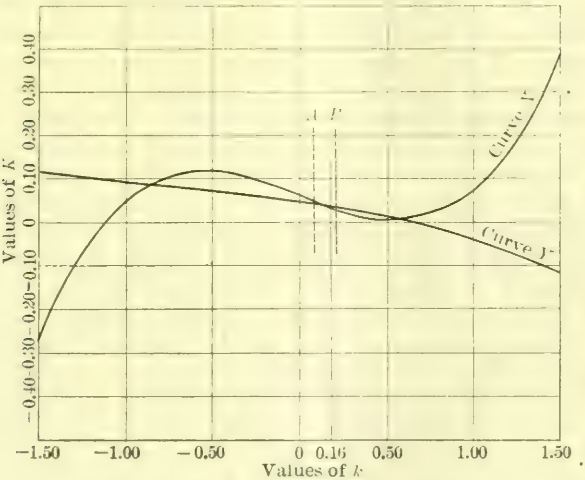
$$M_x = KwL^3 = \frac{wL^3}{4}\ (0.1922 - 0.2444k - 0.076k^2 - 0.0294k^3).$$

Therefore,

$$K = \frac{0.1922 - 0.2444k - 0.076k^2 - 0.0294k^3}{4}.$$

This result requires a complete revision (Fig. 24) of the diagram, Fig. 3, for the simultaneous value of k and K. The line on this dia-

gram, although drawn as a straight line, is, of course, part of a curve (Fig. 25) known as the cubical parabola. So small a portion of the curve is needed between the limiting values used for k and K, that it is a straight line for all practical purposes. The speaker's equation for K gives a line on this diagram crossing the author's line at about the value of $k = 0.16$, which means that, when the ratio of the column's radius to the length of the panel is 0.16, the arm, a, of the loading couple has the same length by each method. It should be observed that the author's distance, a, is measured from the center of gravity of the shearing forces along his section, A, of the panel, whereas the distance, a, by the continuous-girder method is measured from the center of bearing of the quarter panel. Mr. Crehore



Curve X is author's equation $K = \frac{1 - 2.55\,k + 2.67\,k^3}{16}$

Curve Y is speaker's equation $K = \frac{0.1922 - 0.2444\,k - 0.076\,k^2 - 0.0294\,k^3}{4}$

Dotted lines, A and B, include between them the portions of these curves giving the practical values of k in ordinary use, as per author's diagram, FIG. 3.

FIG. 25.

Such an assumption, for the size of the column, as $k = 0.16$, gives the distance, $n = \frac{L}{4}$ (Fig. 23) although m still remains 0.21133 of the diagonal span, S, showing that the cantilever effect reaches out the full quarter span for columns of this size. For larger columns, the suspended load being hung so much farther away, the speaker's method will give a value for the steel in excess of the author's method, showing that the cantilever method of construction is not economical for values of k greater than 0.16, and for all such the

Mr. Crehore.

rods should be placed in the bottom of the slab only. Such a limit might have been inferred from a knowledge of cantilever bridges, as the length of the suspended span is determined there with regard to economy in the whole structure—if made too short, the cantilever spans will be excessively heavy, and if made too long the economy of that style of construction is sacrificed.

In the speaker's opinion, panels 6 ft. long, for example, between columns 2 ft. in diameter (or in that ratio) have their usefulness impaired by the size of the column. Values of k equal to or greater than 0.16 mean just this, and do not seem to be practical values in ordinary use.

Without referring to anything except the simple laws of mechanics of the beam, the speaker thinks he has justified "a result for the maximum stress in the steel smaller than the limiting value determined" in the paper. If the author will revise his calculations to conform with the continuous-beam theory, just explained, he will doubtless find much closer agreement between his estimated stress in the steel and the actual stress developed in observed tests. If the beam theory is to be used in these calculations, it should be fairly applied, without prejudice to the continuous-girder feature of it; and, if this is done, the speaker believes that much of the speculation regarding "dome action" and kindred topics would be satisfactorily explained.

Of course, it is seldom true in actual practice that all panels of such a floor as the one described are loaded uniformly with the same load per square foot, and, if the load be removed from all the adjoining panels, it is well known that the rods in the interior panel will be stressed more highly than if the adjoining panels were loaded; but the continuous-girder effect can never be entirely eliminated, because, in the kind of floor here under consideration, the stresses due to the dead load are more appropriately determined by this method. In any case, with this kind of floor, the stresses in the steel may be calculated far more accurately by applying the continuous-girder method, in accordance with the real conditions of loading, than by the free-end-girder method used by the author. Furthermore, it should be borne in mind that, with a full load on all the panels, the rods in the interior panel would not be stressed so much as with a lighter load on the outer panels and the full load on the interior panel, notwithstanding the author's statement to the contrary.

AMERICAN SOCIETY OF CIVIL ENGINEERS

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PAPERS AND DISCUSSIONS

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THE PHILOSOPHY OF ENGINEERING.

Discussion.*

By Messrs. Lewis M. Haupt, Charles Kirby Fox, A. H. Markwart, and Morgan Cilley.

Lewis M. Haupt, M. Am. Soc. C. E. (by letter).—Mr. Parsons' admirable paper is worthy of being read and known of all men, and especially by the members of the Profession whose duties make them pioneers in the development of the resources which the Creator has placed at their disposal. Mr. Haupt.

The altruistic, fair-minded, open-handed spirit which permeates this "philosophy" is so fully in accord with the Golden Rule that, if it were realized and practiced by engineers in general, it would make them the dominant agency for the general uplift of humanity. The man who is in touch with Nature and correctly interprets her secrets is, of necessity, a lover of truth, and one to inspire confidence in his judgment and integrity.

It is true that a good engineer must be an economist; but economy is not always synonymous with business. "High finance" lives on credulity, fluctuations "on 'change," cupidity, patronage, and other elements, too often created by and sanctioned under the guise of law, and it is erroneously assumed that the more money put in circulation by appropriations from the public treasury, the greater the benefits, regardless of the results. It should not be forgotten, however, that the revenues are derived from the people as a whole, and are doled out to special interests employed by or under the control of the Government, whose main purpose is to serve the appointing power and hold on to the party patronage, so that the larger the appropria-

* This discussion (of the paper by Maurice G. Parsons, Jun. Am. Soc. C. E., published in April, 1913, *Proceedings*, and presented at the meeting of June 4th, 1913), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

Mr. Haupt. tions the greater the power and the stronger the party. This policy of Government soon leads to despotism and profligacy, with resulting distrust and destitution, the remedy for which is to be found in an economic, judicious application of public monies to secure definite results on approved plans demonstrated by experience, and also on free and open competition, with right of appeal—in case of disagreement—to impartial arbiters, and not to the parties who frame the specifications and make themselves the final and sole authority. Such a policy has brought ruin to many honest contractors who have met with unforeseen and unexpected physical obstacles, or with ignorant inspectors.

The author has shown how "many-sided" the well-qualified engineer should be, not only in the various branches of his profession, but in the collateral ones of finance, legislation, organization, and business in general, and not merely an honest man skilled in the technique of his calling; yet how few there be who reach this standard.

If the engineer who knows what is required in the physical world with which he has to deal, does not also assist and advise the Legal Profession or the legislator in the framing of laws authorizing and regulating transportation or municipal improvements, there is great danger of injury and injustice being done to the community; as, for instance, in the case of the disposal of the sewage of densely populated centers like New York or Chicago.

In the latter instance, the quantity of potable water required to render the sewage innocuous was carefully determined, per capita, and an open conduit was constructed, by legal authority and enactment, to discharge that required volume across the Chicago Divide into the Illinois and Mississippi Rivers—a quantity necessarily increasing with the density of population. Now, when it is found necessary to pass 10 000 cu. ft. per sec., to dilute the sewage sufficiently, the Government withholds its permission, leading to the inference that the residents along the route of the outflow must be content to use water contaminated by sewage, injurious to health, and which must increase in its percentage of albuminoids with time; or else, that the Sanitary District must find some other method of disposing of its refuse matter after expending millions in good faith and by approval of the Government. "Business and Government" are inseparable, but the latter should be liberal, not dominant, stable, not fickle, regulative rather than executive in the physical works and operations which may be safely and honestly administered by competitive corporations.

If, as stated, the "good of the people" were the primary object of Government, partisanship would soon disappear, and many of the evils accompanying politics would vanish. We cannot expect such a condition, however, under the *laissez faire* policy of keeping out of politics and letting the machine run itself, in the old ruts. It needs the engi-

neer to prepare the way for a better standard socially, morally, physically, and even spiritually. Then "every valley shall be exalted, and every mountain and hill shall be made low: and the crooked shall be made straight, and the rough places plain": and an highway shall be there, on which the wayfaring man may find occupation and repose. Mr. Haupt.

CHARLES KIRBY FOX, ASSOC. M. AM. SOC. C. E. (by letter).—The writer has read this paper with much interest and thinks that any papers or discussions which will tend to broaden the field of engineers should be encouraged. Mr. Fox.

The author's questions, "Will it pay" and "How much will it cost," reach the core.

Speaking of the old-time engineer, the author says: "All this time the engineer was, primarily, a builder without special training—with nothing but his judgment and common sense as guides." From old and new works and from plans which the writer has seen and heard about, he is inclined to think that these two items, with a liberal allowance of loyalty and "stick-to-it-ness," are the principal qualifications of an engineer. He cannot have judgment unless he has acquired a good education and has had extensive experience.

In connection with the author's general statements, it might be worth while to take into consideration the testimony given in the preface of Wait's "Law of Operations Preliminary to Construction in Engineering and Architecture":

"It is not the mere competency to design, draft, lay out, and superintend work that gives reputation to an engineer. This is work done by assistants who are comparatively unknown to the profession. The men who control and direct the work are men of broad ideas and business capacity, whom companies and proprietors expect will look after their business conservatively and hold their investments secure and profitable. This, it is contended, depends largely upon their business and legal training. Without this training graduate engineers find their many technical qualifications without weight in the estimation of their employers, and they feel it keenly when men with a general education are taken from the ranks of clerks and office help and are given direction of work as superintendents and managers wholly on account of their knowledge of the business policy which directs the financial operations and because they know from association and study how to decide ordinary questions of business and law."

Following along the lines of broader business policy for engineers, H. T. Cory, M. Am. Soc. C. E., recently presented before this Society a very interesting and instructive paper on "Irrigation and River Control in the Colorado River Delta." He not only described the engineering features, but gave a complete financial and commercial summary of this important work. This is the first time the writer has seen this important part of a construction enterprise treated in this manner. It is now well known that the overhead charges, such as promotion,

Mr. Fox. financing, discount and interest on bonds, general charges, etc., amount to from 50 to 100% of the cost of the construction items. Many papers are written on the technical side of engineering, but practically none on the business and financial side.

At one time it was considered unprofessional for an engineer to have anything to do with the contractors or actual construction. In other words, his work was confined to the survey, designs, and inspection. Now, there is hardly a contracting company which is not handled wholly or in part by engineers.

Engineering has been defined in many ways as "the art of making the dollar go the farthest," and "the art of directing the great sources of power in nature for the use and convenience of man." Why not combine these and define engineering as the art of directing the great sources of power in nature for the use and convenience of man in the most economical manner possible?

Mr. Markwart. A. H. MARKWART, ASSOC. M. AM. SOC. C. E. (by letter).—This is a very thoughtful paper. The engineer is becoming more and more a necessary and important factor in the modern social and economic system, and such papers tend to bring out this point in a dignified and scholarly manner.

In this day, labor is of value and creates value, and the highest efficiency thereof is constantly sought to the end that there may be no economic loss. The use of labor and the expenditure of capital in an efficient manner is the function of the modern engineer. In remotely ancient times human life had but little value, and a Pyramid was conceived to satisfy a ruler's whim or furnish for him a monument by which to be known after he ceased to exist. Though it is true that the ancients constructed such monuments with considerable skill, and one wonders how and by what means they were carried out, there was no wealth created thereby, as we understand the term "wealth"—the result of human activity.

Modern engineering is the result of necessity, and offers a peaceable field for achievement. The construction of such a great work as the Panama Canal, for the benefit of humanity at large, calls forth one's unbounded admiration. The engineers on this undertaking have made a personal sacrifice. They have given time and attention to a work which isolates them for a long period, and acts to their personal disadvantage in many ways. The emolument received is small, and they are removed from their usual associates and haunts, causing them to be more or less forgotten; the gap made is soon closed. Truly there is much food for thought when one realizes the obligation of society to such fore-lopers.

The engineer of ancient days knew nothing of the science of engineering as it is now understood. His work was the result of experiment. If a wall 1 ft. thick was insufficiently strong and fell, one

2 ft. thick was provided in the next venture. Beware of the engineer of the present day who constructs his work in this manner. It is the tendency of the engineer to be, not a parasite, but a creator, and a creator with constructive and not destructive theories. Furthermore, by training, his impulses are those of the conservationist. Few engineers would knowingly waste the materials and resources at their disposal. These are tendencies in the right direction, and are fundamentally economic in theory. Mr. Markwart.

Normally, the engineer has but little interest in public life or political activity. This seems peculiar when we reflect that all his training has been along a line which tends to produce the careful and logical thinker. He should be a factor in any progressive régime, whether political or commercial, as he is not hedged in by precedent or prejudice. Generally speaking, the engineer has a responsive and receptive mind on ordinary problems, and he seeks to be shown the truth.

The writer at this point would call attention to the apparently increasing demand on the engineer in the architectural problems of to-day. It would seem that the architect is gradually and voluntarily giving up his place as master builder. He does not fill the same office as did Michael Angelo, who was in turn, sculptor, painter, architect, engineer, and poet. On the contrary, the modern architect does not allow himself to qualify in this broader field of art; he assumes his most important work to be along esthetic lines alone. He is more concerned about the exterior appearance of his building than about any other feature. The façade, color scheme, and floor plan seem to hold the major part of his attention. Whether the construction of the proposed building will be a good commercial proposition is of no concern to the architect; rarely does he make a logical and convincing analysis of conditions to be met or problems to be solved. This is not a criticism, but a statement of a condition. Such matters as the financial report, the economic design, and the execution of the scheme are frequently left to the engineer. This is in support of the general idea advanced by Mr. Parsons, and is a confirmation of the opinion that the engineer is entering a broader field of activity.

There is at present a movement on the part of engineers to develop a code of ethics. This should be encouraged and fostered. The architect has his code of ethics, and, generally speaking, it is a recognized and established standard for the profession, even in the eyes of the layman. All such codes have, as a component part, a schedule of fees, and though, on the face of things, this may appear to be mercenary, there is no doubt that there is considerable necessity for such a feature. The engineer should be adequately compensated, the compensation being measured in terms of the service rendered. A manifestly low price or insufficient compensation is an argument for a poor

Mr. Markwart.

article or an inadequate service. A proper compensation must needs result in a better moral standard, and any code of ethics should include a schedule of prices, to bring this about.

Mr. Parsons has mentioned the ever-increasing demand for engineers in the various political, social, and commercial fields. It is becoming more and more the function of the engineer to act as adviser in actions or disputes between labor and capital; he is becoming the scientific purchasing or selling agent for large corporations; he assists in the valuation of property, for sale or rate-fixing purposes, and he frequently takes up sociological problems of considerable moment.

Engineering, from a broad viewpoint, requires a large supply of common sense, executive ability, and action. Our colleges should take this into consideration in their teachings, together with the question of moral training, to the end that to be an engineer is to be one who can be relied on to operate successfully under a high moral standard, so that his opinion and advice will be sought when other sources fail.

It has been said that the engineer frequently looks after his client's financial interests better than his own. There is probably considerable truth in this remark, and such a condition is inconsistent when we consider the broad responsibility of the modern engineer. This must be avoided, for there is something in the theory that personal financial prosperity is to some degree a measure of one's success. Prosperity, to some degree, promotes higher ideals, and, after all, the higher ideal is that which should be attained in all walks of life.

The old theory that a business should charge all that the traffic will bear is false, and other advanced and broader theories are taking its place. Good service is now, and will continue to be, considered as that which is to be rendered. Competition of service will in the future be the spur which actuates opposing concerns. This principle is essentially with us and in operation. From now on, a reduction in price is not necessarily going to obtain the business. Superior and improved service will have to be rendered. The "Philosophy of Engineering" very clearly brings out this phase of modern business.

It is only a question of time, in corporation activities, when many mooted points will be settled, and very probably by the engineer. For instance, what consideration should be given in the case of free rights of way as regards rate-fixing purposes? Should the public be a partner to this extent? Again, in continual change of methods, the cost of plant equipment is being constantly reduced. Early-day plants cost more than latter-day plants, resulting in cheaper service to be furnished by the latter-day plants. Does it seem fair to "junk" the early-day plant which was built in good faith? Further, the unearned incre-

ment principle will be put on a firmer basis. All such are problems that should be solved by the engineer. Mr. Markwart.

The writer disagrees with the author as to whether the "Money Trust" is an absolute necessity. The question of proper control is so complicated that it is doubtful whether all conflicting points could be consoled. A powerful money trust unquestionably destroys private initiative. Many an enterprise starts as a result of individual effort. We should do nothing to prevent such initiative, for the reason that many worthy movements would thereby remain unborn. Individual initiative must continue, and to continue there must be incentive, and to have that incentive there must be the anticipation of personal profit. New or under-developed localities would remain dormant if left to the money trust alone.

The author suggests the possibility of an economic rate of investment as regards the public at large; a commercial clearing house, as it were. This is Utopian, but is an interesting thought. It would be quite possible, however, in individual cases of investment, to determine at what rate, for instance, ore bodies should be exhausted in order to produce the most economical results, in the broadest sense, time being considered. To obtain the ideal expenditure is a nice problem of the calculus, similar to, but more complicated than, the determination of the economical diameter of a pipe line in a power plant so that the value of power lost by friction bears the proper relation to the value of the horse-power generated.

The writer will conclude by agreeing thoroughly with the author that the commercial or big business is here to stay, but we must temper it with the esthetic, to the end that what we do is good and great, whether it be the development of an idea or a piece of construction. Our acts and our engineering should be good to behold. Even a monument here and there, as in the time of the ancients, will do us no harm.

Morgan Cilley, Assoc. M. Am. Soc. C. E. (by letter).—This paper deals with a phase of the Profession which has received very limited thought; indeed, too little; but, of course, pressure of affairs has prevented the engineer from devoting to it the time which, otherwise, he would have liked to give. Mr. Cilley.

It is not less important than the subjects which receive more attention, and the neglect which it has suffered has been responsible to a large extent for the lack of appreciation for the engineer and his absence from the councils of higher affairs.

The neglect of kindred lines of study in college is the beginning of the engineer's mistake; he too often sees too much importance in the technical side of his course, and in after life too readily accepts the position of a servant too engrossed in technical details to be bothered with, and, as it is sometimes expressed, "to bother with," managerial coun-

Mr. Cilley.

cils. Ernest McCullough, M. Am. Soc. C. E., in his paper "Engineering Education in Its Relation to Training for Engineering Work,"* handles this side of the subject exceedingly well in the studies he recommends for the third-year course, and it is in the perfunctory attention to the subjects mentioned that lies the lack of appreciation for the engineer's importance in the social structure as brought out in Mr. Parson's paper. Does he display the interest in that social structure which would inevitably draw him into the fabric of big things, or, possessing that interest, allow it to languish beneath his engrossment in details?

In fact, the engineer can learn a great deal from the salesman and advertiser. Publicity will benefit the engineer. Just as in business, so in engineering, the consumer has to know where to look for his engineering service. Among engineers there is no need of the strict code of ethics that exists among medical men. Where is the public to find the capable and efficient man, if that person keeps himself practically unknown outside a very narrow circle of acquaintances?

Then, when his opportunity comes, he is at a loss how to present his facts, ideas, and convictions in the briefest yet most telling way. To accomplish this he must have in mind the philosophy of engineering, a working knowledge of psychology, and experience in public speaking, backed by convincing assurance. In fact, he must be a salesman. An engineer from one of the larger engineering offices of New York City, one who had charge of a number of improvement works, once boasted to the writer of having, that day, gone before a meeting of a town council, in connection with his work, and made a telling speech in which he persuaded it to make certain additions to the plans. An average traveling salesman would have thought no more of that than that engineer would have thought of accomplishing a survey which was a little out of the ordinary.

Continuing Mr. Parson's paper, we read:

"This rigid requirement, that an undertaking must be commercially feasible, strangles the industrial application of many scientific possibilities."

This is only too true, and yet the development of scientific possibilities, which may have seemed at first to be lacking in commercial feasibility, has made the Edison Laboratories the greatest center of valuable invention of history, and also has put the German nation, on account of its government laboratories and government-aided private investigations, in the foremost rank of chemical knowledge and development.

Mr. Parsons argues the importance of the development of scientific possibilities which tend toward the ultimate good of humanity, and on this bases his convictions as to the necessity of a "money trust." Then, as the government is the people, and a money trust holding the accumu-

* *Transactions*, Am. Soc. C. E., Vol. LXXV, p. 1090.

lated savings of a nation is a necessity, it and the people's government should be one and the same. Mr. Cilley.

The passing of Mr. J. P. Morgan is conceded by all to mark the beginning of a different era of financial arrangements. The economic ills mentioned by Mr. Parsons are traceable to human frailties, and, recognizing this, the people are insisting that their accumulated savings shall not be risked in the power of one man or group of men, regardless of irreproachable character or integrity, unless he or they are directly responsible to them for their acts.

The United States Government has departments which have for their work functions in other fields, similar to those mentioned by Mr. Parsons for his central clearing house, and their acts have the power of the people's government behind them. Then why should it not have a department with the functions the author suggests?

Further, as it would require engineering of the highest order, and in which the Profession would be of greatest importance, why should not this Society, in conjunction with the other great engineering organizations in the country, take the initiative in a movement toward that end? As engineers have become much better recognized, concerted action on their part would certainly receive attention. If recommendations are based on the deepest thought, give evidence of having been thoroughly considered, be devoid of the least traces of personal or professional ambition, and carry with them the conviction that they are for the far-reaching good of humanity, the movement will succeed.

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THE ELEVATION OF THE TRACKS OF THE PHILADELPHIA GERMANTOWN AND NORRISTOWN RAILROAD PHILADELPHIA, PA.

Discussion.*

By Messrs. J. P. Snow, E. W. Lewis, and Charles Rufus Harte.

J. P. Snow, M. Am. Soc. C. E.—It will be of interest to learn from the author if the scheme for this work was decreed by some public board, as is customary in some of our States, or by agreement between the City and the Railroad; also, if all matters of detail, like handling telegraph wires, which it is stated the City would not help pay for, were settled on in the original agreement or decided on as the work proceeded; also, if the Railroad was compelled to pay one-half the total cost of widening streets, where that was done. Mr. Snow.

In connection with building the temporary trestle, would it not have been entirely safe to have used timber sills resting directly on the street surface, and much cheaper than to build concrete footings? Where there was any question of the bearing value of the ground, cross-planks could have been placed under the sills. Apparently, this trestle was built along the street, the surface of which must have been well compacted and probably much better able to sustain loads than the soil beneath. The load per square foot under a simple sill would not much exceed 5 tons per sq. ft., and, with 30-in. cross-planks under the sills, it would reduce to about 2 tons, which is a safe load on very ordinary soil.

For temporary work, it is good practice to use timber in contact with

* This discussion (of the paper by Samuel Tobias Wagner, M. Am. Soc. C. E., published in May, 1913, *Proceedings*, and presented at the meeting of June 4th, 1913), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

Mr. Snow. the ground, and oftentimes the top crust of soil is capable of carrying a greater concentrated load than the material below.

Mr. Lewis. E. W. LEWIS, M. AM. SOC. C. E.—The speaker would like to ask Mr. Wagner how near the original estimate the total cost of the work has proved to be, if he is permitted to give the figures. Some railroad corporations are averse to giving out any figures of actual cost of improvements, and the speaker does not wish to place the author in an embarrassing position. The cost of extensive improvements, in a number of cases which have come under the speaker's observation, has largely exceeded the estimates, in some cases as much as 100 per cent. It is a matter of considerable interest, particularly to those engineers directly involved, to have a comparison between the estimated and the ultimate actual cost.

Mr. Harte. CHARLES RUFUS HARTE, M. AM. SOC. C. E.—It would be interesting to know the details of the drainage system of those bridges in which the troughs were filled with concrete.

On the Boston elevation of the New York, New Haven and Hartford Railroad, hollow trough bridges, similar to those described in this paper, were used to a considerable extent, and, as in Mr. Wagner's case, there was quite a little difficulty in the matter of drainage.

Each trough had a drainage hole in which a copper thimble was expanded. Not only was it very difficult to keep this thimble tight, but other and entirely unexpected troubles developed. The thimbles were intended to discharge into a copper trough running parallel with the street, which in turn emptied through leaders into the sewer. The trough was suspended from the bridge by wires attached to the centers of spanners over the top of the trough, and in the first installation these spanners were highest in the center. Condensed moisture gathered on the steel, ran down the wires to the spanner and then, instead of decently dropping into the trough, flowed on top of the spanner and over the edge of the trough and then dropped into the street. It was remarkable how often this occurred, and on what valuable clothing the water managed to fall. Until the cause was located and the trouble corrected by depressing the spanner at the center below the level of the ends, the Claims Department was kept busy with complaints.

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IRRIGATION AND RIVER CONTROL IN THE COLORADO RIVER DELTA.
Discussion.*

By Messrs. F. T. Robson, Andrew M. Chaffey, C. E. Grunsky, Clarence K. Clarke, and U. S. Marshall.

F. T. Robson, Assoc. M. Am. Soc. C. E. (by letter).—Under the heading, "Salton Sea", the author makes two statements which are quite noteworthy, and not to have been expected. The first is that the land uncovered as the sea recedes is being cultivated with entire success, and presumably with no preliminary treatment to remove soil alkalinity. This is the more significant because, before the formation of the sea, this land had an alkalinity so great that it was condemned by the soil surveys of the United States Department of Agriculture, mentioned elsewhere by the author. The soil alkalinity of this part of the desert is in general greater than throughout the portion first cultivated and for which the Imperial Area Soil Survey was made. Since then it has been covered for from 1 to 6 years by water which, according to Tables 20 and 21, was in 1907 more than one-tenth as high in soluble solids as ocean water (and generally similar in the proportion of the various elements), and is undoubtedly growing constantly stronger because of the submerged salt beds. Nevertheless, independent inquiry confirms the statement as to the successful cultivation of the land which is being exposed. Mr. Robson.

The other interesting and surprising statement is that the gross evaporation from the sea is only 6 ft. per annum. The writer has also taken the trouble to check this figure—and has found that it should be only 67 in.—and in doing so he has collected some information bearing on this point which it is thought will be of interest.

* Continued from May, 1913, *Proceedings*.

Mr. Robson.

The opportunity offered at the Salton Sea for careful determination of gross evaporation from large areas of water surface, and the relation of this evaporation to that from small pans and evaporators, was recognized by the officials of the United States Weather Bureau, and from October, 1907, to the end of 1910, a large amount of work was done there.

Special studies of evaporation loss from the surfaces of lakes and reservoirs were begun by the Weather Bureau, under the direction of Professors Bigelow and Marvin, at Reno, Nev., about August 1st,

FIG. 40.

1907, the main headquarters being transferred to the Salton Basin near Salton in the following October. Observations were also made simultaneously at the near-by points, Indio, Mecca, Mammoth, and Brawley, and at the following distant points: Phœnix, Ariz.; Eagle and Carlsbad, N. Mex., these being at low elevations in these States; Mitchell, Nebr.; Howell, Wyo.; Rupert and Boise, Idaho; Hermiston and Klamath Falls, Ore.; North Yakima, Wash.; Fallon, Nev.; Lake Tahoe, Cal.; on the Rocky Mountain Plateau up to an elevation of

6 000 ft.; Birmingham, Ala.; Cincinnati, Ohio; Tupper Lake, N. Y.; and Lockport, Ill., in the districts east of the Mississippi River. Most of the western points selected were stations of the U. S. Reclamation Service, and at most of them evaporation observations were taken at 2, 6, and 10 A. M. and at 2, 6, and 10 P. M., though in a few cases observations were taken only at 6 A. M. and 2 P. M., which were found to be about the time of minimum and maximum evaporation, respectively, and from which, it has been shown, very accurate results can be obtained by taking the mean values. Mr. Robson.

The final bulletin on the data collected and the conclusions derived therefrom, though promised to be issued in 1911, has not yet appeared. It is hoped that it will not be much longer delayed. However, Professor Bigelow has given a summary of results and deductions in a preliminary report.* This preliminary statement does not contain the observed data, which, however, are abstracted by Professor Bigelow in the "Abstract of Data, No. 4", issued by the Weather Bureau, being "A Provisional Statement Regarding the Total Evaporation by Months at 23 Stations in the United States, 1909-10".

The preliminary experiments at Reno indicated that a large body of water loses only about seven-tenths as much as a small pan set in a dry place outside its vapor sheet. The further experiments indicated the loss to be near 65%, in the opinion of Professor Bigelow; and the results at the Salton Sea, properly corrected, in the writer's opinion, indicate the proper coefficient to be still lower, namely 60 per cent. This relation, from the practical point of view, is the most important fact brought out in the work at these various stations, particularly in that at Salton. At this point four towers were built: No. 1 about 1 500 ft. from the water's edge, No. 2 near the Southern Pacific trestle over Salton Creek about 500 ft. from the shore, No. 3 ¾ mile west, in 40 ft. of water, and No. 4, which is 120 ft. high, 1½ miles west, in 55 ft. of water (depths in 1909). These towers, though made as stiff as possible, were found to have a slight vibratory motion, even in quiet weather, and hence the water in the evaporation pans required to be damped in oscillation by submerged partitions.

The important results, as given by Professor Bigelow in the preliminary report referred to, are:

1.—That the wind velocity was so different at various heights, 0, 10, 20, 30, and 40 ft. above the ground—amounting often to 30% less at the ground than 10 ft. above—that every evaporation pan must be supplied with its own anemometer wherever evaporation observations are made, whether on land or on large bodies of water.

2.—That pans of different sizes evaporate at different rates, and

* *Monthly Weather Review*, February and July, 1910, pp. 307 and 1133, "Studies on the Phenomena of the Evaporation of Water over Lakes and Reservoirs."

Mr. Robson. these rates were found to vary approximately as the expression, 0.023 $(1.23)^n$, where n has the following values:

$n = 0$ for large open-water surfaces,

$n = 1$ for 6-ft. pans,

$n = 2$ for 4-ft. pans,

$n = 3$ for 2-ft. pans,

$n = 4$ for ordinary dry air.

This variation seems to be due to the banking up of the vapor on the leeward side under the action of the wind, and because the small pan clears much more completely of vapor, and evaporation takes place into a mixture of air of different contents according to the size of the pans and the force of the wind.

3.—The formula finally suggested by Professor Bigelow is (c. g. s. units):

$$E_d = C_2 \frac{e_s}{e_d} \frac{de}{d\,s} (1 + 0.070\ W),$$

where E_d = Evaporation in 24 hours (one day), in centimeters;

C_2 = Coefficient, found to be 0.138 $(1.23)^n$;

e_s = Saturation vapor pressure at temperature of the water surface, designated by s;

e_d = Saturation vapor pressure at temperature of the dew point in the air near the water;

e = General symbol representing vapor pressure;

E = General symbol representing depth of evaporation;

$\frac{e_s}{e_d}$ = Expression for the gradient (use Crelle's tables);

$\frac{de}{ds}$ = Expression representing the change of vapor pressure with temperature, s, taken. This quantity is merely the tabular difference in ordinary vapor pressure tables at the temperature under consideration (use Manual Table V).

W = Wind velocity, in kilometers per hour.

It is proposed to substitute this formula for that now in general use, which was proposed by Dalton in 1803 and may be written as follows (same notation):

$$\frac{dE}{dt} = C\ (e_s - e_d)\ (1 + aw),$$

where t = time, and C and a supposed by constant terms,

or $E_d = 0.036\ (1.23)^n\ (es - ed)\ (1 + 0.070\ W)$ using the values of the constants deduced from these experiments at Salton.

Mr. Robson.

4.—That water in pans of the same size evaporates at the same rates at 4 000 ft. elevation as at sea level, and hence the formula does not contain any barometer pressure term.

5.—The recommended formula has no annual period in the C_2 coefficient; the diurnal period is very small.

6.—A pan of very fresh water was allowed to evaporate alongside a pan filled with brackish Salton Sea water, which was gradually concentrated by adding water from the sea from November to May without emptying the old water. The brackish water evaporated a little slower than the fresh water, to the amount of 2% in April and May.

7.—The actual fall of the Salton Sea level from June 1st, 1909, to June 1st, 1910, was 51 in., and Professor Bigelow estimated that the rise was 12 in. due to inflow from the Alamo and New Rivers, and there were 6 in. of accretions from annual precipitation, making a total gross evaporation of 69.0 in. This total checked with results computed by formula from observed data necessary.

8.—Practically, it was the conclusion that engineers would necessarily have to adopt a standard pan and reduce the observed readings to the open-water surface, as explained above. Thus, the evaporation from a 4-ft. standard pan, when corrected for temperature and wind, and multiplied by 0.66, is very close to what observation suggests. If a water thermometer on a small raft in the lake measures s_0, and e_s and e_d are determined by using a sling psychrometer, through t and t_s, and the wind velocity by an anemometer as near the water surface as possible is W, then $C = 0.138$ for a 24-hour interval. In the formula, the mean values taken at readings made about 6 A. M. and 2 P. M. should be used.

The writer has checked the estimates of Professor Bigelow as to the inflow from the Alamo and New Rivers, and the increase due to the rainfall and run-off from the water-shed, from all the available data (of which considerably more exist now than when Professor Bigelow did his work). It is known that there are no springs or underground sources of supply discharging into the basin, because, until very recent years, the sea contained no water, and salt beds in the bottom were regularly mined. The rainfall is very light, consequently the run-off is small. From the time when the Colorado River was finally rediverted (the middle of February, 1907) to date is 6 years, and it seemed to the writer that the results should be checked to obtain an average for this entire period, rather than for the year from June 1st, 1909, to June 1st, 1910, which was taken by Professor Bigelow.

In determining the inflow, it is possible to utilize the sea itself as a large measuring tank in which to measure the combined rainfall on the water surface and the run-off from the drainage area due to rainfall—proper correction being made for the regular inflow from the

Mr. Robson. Alamo and New Rivers—by using the daily gauge heights or elevations of the water surface.

As a first step in obtaining the average evaporation for the entire 6-year period, the difference in elevation of the water surface on April 1st, 1907, and April 1st, 1913, was found to be 26.10 ft.

If, then, (1) the total precipitation on the sea itself, plus (2) the total run-off into the sea, plus (3) the total discharge of the Alamo and New Rivers into the sea for the same period, be added to this 26.10 ft., the result will be the total loss due to evaporation—percolation being considered as of no consequence.

a.—The writer prepared a table of the rainfall for each month of each year, as observed at Brawley, Calexico, Heber, Imperial, Mammoth, Mecca, and Salton, all these points being within the drainage area and fairly well distributed. It was then assumed that the total rainfall at all these stations, divided by the number of stations, would give a fair average of the precipitation on the sea itself. The total thus found for the 6-year period was 16.59 in. or 1.38 ft.

b.—A table was then made showing the decrease in elevation of the water surface for each month of the period, and the decrease for each month was compared with that for the corresponding month of the other years. It was found that the decrease in one month compared very closely with that for a corresponding month in another year, except in cases of unusual rains or other known causes. Eliminating these months, a total was then made of those remaining, and the result was divided by the number of months comprising the sum. The average thus found was assumed to be the normal average decrease for that month. Sufficient amounts, corrected for excessive rainfalls on the sea itself, were added to bring the eliminated months up to the average, and these additions were considered as the run-off or inflow due to precipitation. This total was 15.00 in., or 1.25 ft., for the 6-year period. The results obtained by this method were checked by examination of the daily precipitation records for these various Weather Bureau Stations. In such desert country, where the rainfall is scant, that which does occur is frequently in intense storms or in local cloudbursts. Monthly records, therefore, are of little value as indicating the probable run-off, and each storm at each observation station must be considered, instead of the monthly totals. Only two or three heavy precipitations extending over the entire water-shed occurred during the 6 years, the heavy rainfalls usually being rather local in character and in the nature of cloudbursts. The total number of such heavy precipitations throughout the period at all these stations, however, was surprisingly small, and the daily gauge heights of the sea surface for several days was carefully examined in connection with each of these heavy rains. In this way a very good check was obtained on the foregoing method of deter-

mining the total inflow into the basin from its water-shed—exclusive of the New and Alamo Rivers. Mr. Robson.

c.—The discharge of the Alamo and New Rivers has been observed, and a rating curve has been applied only for a period from June, 1909, to October, 1910. Based on the records published in Water Supply Paper No. 300, and from information kindly given to the writer by Mr. Cory from his personal records, the following rises in the elevation of the lake surface have been determined, and are believed to be very close to the truth.

To January 1st, 1908	0.62	ft.
From January 1st, 1908, to January 1st, 1909	0.65	"
" " " 1909 " " " 1910	0.68	"
" " " 1910 " " " 1911	0.71	"
" " " 1911 " " " 1912	0.75	"
" " " 1912 " " " 1913	0.78	"
Total	4.19	ft.

To sum up, then, the evaporation has been as follows:

Loss in elevation of lake, as shown by gauge heights	26.10	ft.
(1) Total rainfall on lake surface	1.38	"
(2) Total run-off from rainfall	1.25	"
(3) Total discharge from Alamo and New Rivers	4.19	"
Total evaporation, April 1st, 1907, to April 1st, 1913	32.92	ft.
or a yearly average of	5.58	ft.
or	67.02	in.

as compared with 69.0 in., the total gross evaporation found and estimated by Professor Bigelow for the 1-year period, June 1st, 1909, to June 1st, 1910.

Table 31, containing observed data at Salton Sea, is taken from "Abstract of Data, No. 4," by Professor Bigelow, referred to previously. The figures for Nos. 1, 2, 3, and 4, for March, April, May, and June, were interpolated from curves plotted from records of previous years, and found by experience to give close results.

At the stations outside of the vapor sheet, at which observations were taken, for a 6-ft. pan on the ground, the total evaporation observed was:

Indio	119.33	in.
Mecca	107.81	"
Brawley	103.55	"
Mammoth	125.53	"
Total	456.22	in.
Average	114.055	"

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TABLE 31.—TOTAL EVAPORATION, BY MONTHS.

NUMBER.	1.		2.		3.		4.		5.		6.		7.	
STATION.	SALTON SEA. TOWER NO. 1. 1 500 FT. INLAND.		SALTON SEA. TOWER NO. 2. 500 FT. AT SEA.		SALTON SEA. TOWER NO. 4. 7 500 FT. AT SEA.		INDIO, CAL. 10-FT. STAND.		MECCA, CAL. 10 FT. STAND.		BRAWLEY, CAL. 10-FT. STAND.		MAMMOTH, CAL. 10-FT. STAND.	
	(1)	(5)	(1)	(5)	(1)	(5)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Position of pans, etc.	Ground $D. = 2$ ft.	40 ft. $D. = 2$ ft.	2 ft. $D. = 4$ ft.	45 ft. $D. = 4$ ft.	2 ft. $D. = 4$ ft.	45 ft. $D. = 4$ ft.	Ground $D. = 6$ ft.	10 Ft. $D. = 2$ ft.	Ground $D. = 6$ ft.	10 ft. $D. = 2$ ft.	Ground $D. = 6$ ft.	10 ft. $D. = 2$ ft.	Ground $D. = 6$ ft.	10 ft. $D. = 2$ ft.
January	5.08	7.05	3.61	5.14	3.41	4.69	3.18	5.52	2.92	5.46	3.05	5.32	4.24	6.47
February	7.42	9.45	5.01	7.17	5.09	7.40	5.08	8.83	5.00	8.75	5.00	8.00	5.67	8.89
March	12.50	13.25	6.75	9.00	6.95	9.50	7.50	12.09	8.07	11.87	8.00	11.00	8.99	11.65
April	15.75	17.25	9.00	10.50	8.75	11.50	12.05	19.17	10.87	16.96	10.74	16.04	12.02	17.13
May	19.00	20.50	11.00	13.00	10.50	14.00	15.84	25.13	12.72	21.26	13.79	21.57	15.52	22.00
June	21.50	23.50	13.50	16.75	13.00	16.75	16.11	26.69	14.23	21.56	13.68	20.21	16.75	24.17
July	22.15	24.96	14.77	18.63	14.03	17.98	16.34	27.24	15.21	22.59	14.14	20.96	18.00	25.68
August	18.50	21.21	12.53	15.03	12.19	15.33	13.78	23.05	13.22	20.41	11.26	21.18	13.73	18.15
September	15.50	19.47	12.40	15.18	12.08	15.40	12.37	21.13	10.29	16.86	10.15	16.30	12.16	17.04
October	13.19	17.20	9.20	12.21	9.24	13.02	8.91	16.85	8.17	12.43	6.99	11.58	9.49	14.72
November	7.49	10.05	6.21	8.13	5.96	7.48	5.17	9.44	4.13	7.15	4.07	7.01	5.26	8.08
December	6.42	9.55	4.67	6.97	5.25	6.97	3.00	5.25	2.98	4.65	2.68	4.57	3.70	5.12
Year	164.50	193.44	108.65	137.71	106.45	140.02	119.33	200.39	107.81	169.95	103.55	163.74	125.53	179.10

The total evaporation, as determined by the writer, was 67.02 in. Hence the coefficient to be used in converting the observations from a 6-ft. pan on the ground outside the vapor sheet, and in a desert country, to the total loss from a large water surface, seems to be $\frac{67.02}{114.055}$, or 0.59, or, say, 0.6. Mr. Robson.

ANDREW M. CHAFFEY, ESQ. (by letter).—Careful reading of Mr. Cory's paper leaves the agreeable impression that he has sought to be fair and unprejudiced in handling a very complicated subject. Two other publications dealing with the Imperial Valley project have appeared, one mentioned by the author*, and another† consisting of short monographs by settlers, promoters, etc., gotten out by E. F. Howe, editor of the *Imperial Valley Press*. Both are rambling sketches, rather than histories, unsystematic, full of inaccuracies, and partisan and misleading statements, and hence untrustworthy and unsatisfactory. Mr. Cory's paper, therefore, is to be regarded as the first serious history of Imperial Valley, and will unquestionably be heavily drawn on by future writers. It is most fortunate, therefore, that it is being fully discussed, its inaccuracies pointed out, its engineering and historical matter supplemented by those qualified to do so, and, more particularly even, that several of the facts brought out by the author may be gathered together so that the reader interested in details may not fail to catch their true significance. Mr. Chaffey.

The writer was associated with his father, Mr. George Chaffey, in the management of the project from April, 1900, to February, 1902, and, for more than twelve years, has been collecting original documents and data relating to Imperial Valley. To these, doubtless much the most complete in existence, the author, unfortunately, did not have access, due to the fact that, curiously enough, he and the writer did not become acquainted until after the appearance of this paper.

On page 1392‡ the author states that the first practical step toward the irrigation of the Colorado Desert was the incorporation of the California Development Company in 1896. The writer feels that this is exceedingly misleading. Incorporating a company with large capital stock, appropriating vast quantities of water, by posting notices and recording the same, all at most nominal cost, acquiring options for small cash payments, getting out reports setting forth the merits of a project, and hawking the scheme about in financial centers, cannot rightly be considered as "practical steps" toward carrying out any enterprise. It is just this sort of "shoe string" promotion which Mr. Mead doubtless had in mind when writing his discussion on this paper (page 563§) and pointing out the folly of letting irresponsible

* "Born of the Desert," by C. R. Rockwood, 1909-10.

† "The First Decade," Imperial, 1910-11.

‡ *Proceedings*, Am. Soc. C. E., for November, 1912.

§ *Proceedings*, Am. Soc. C. E., for March, 1913.

Mr. Chaffey.

companies go ahead without any public supervision whatsoever. On the contrary, the first "practical step" was taken when Mr. George Chaffey signed the contract (April 3d, 1900) to build canals into Imperial Valley. Many readers of the paper will undoubtedly get the impression from it that the California Development Company was at such time a going concern, and that its promoters had already produced tangible results. As a matter of fact, though it had been in existence nearly four years, it had as assets the two options on land—one in Mexico and one in California—mentioned by the author, as to each of which the Company was in default, and an idea, a project of large and attractive proportions on which not one shovelful of earth had been turned, and toward the consummation of which not one single practical step had been taken. Its obligations, aside from its capital stock, were various debts, aggregating a considerable sum, and $350 000 worth of what was called land scrip—issued prior to 1900 at 10 cents on the dollar and dissipated in promotion expenses—which was retired at face value in cash or in exchange for water stock of the various Mutual Water Companies at market price at the most inopportune time, namely, just before the water distributing system was completed in the valley.

The contract recited that the California Development Company owned, through a subsidiary Mexican Company, 100 000 acres of land in Mexico through which the canal must run. But for this representation (which turned out to be untrue) the contract would assuredly not have been made. The idea in reality was free to Mr. Chaffey, or to any one else for that matter. Indeed, Mr. Chaffey, at the request of Dr. Wozencraft, had considered the proposition in the early Eighties, before the later promoters had even heard of it.

To say, therefore, that at this date (April, 1900) there was a "practical change of management," that the engineering policy changed, or that "original plans were not carried out," is to create an absolutely erroneous impression. To quote Mr. Chaffey himself:

"I saw a way to accomplish the object with the means at my command by disregarding the Rockwood Survey altogether, adopting another line by which the bank of the canal would be made to serve as a levee to prevent the flood waters of the Colorado from finding their way into the Alamo, and utilizing many miles of that natural channel for the main canal."

This contract of April 3d, 1900, provided that Mr. Chaffey was to construct such canals as were necessary for the purpose of taking water from the Colorado River just above the Mexican boundary line to where the central main canal intersects the same boundary line in Imperial Valley, "said canals to have a capacity sufficient to deliver four hundred thousand acre-feet of water per annum at said last-named point"; that no more money should be expended "than is neces-

sary in such construction"; that the construction cost of such canals should not exceed $150 000; that such construction was to be "at actual cost to first party"; that Mr. Chaffey was to receive $12 000 per annum salary for five years, payable when the Company was able to pay it, and one-quarter of the Company's capital stock; and that he should have charge of the Company's finances as well as its engineering works during that period. Mr. Chaffey.

It is felt that the foregoing abstract of this contract will suffice to indicate clearly its fairness, to say the least, to the Company.

From this date until the contract was terminated—April 3d, 1900, to February, 1902—Mr. George Chaffey and associates furnished the necessary money, and, dividing the engineering responsibility with no other person, designed and built the diversion works and located and constructed the main canal—including the Central Main west of Sharps Heading and in the United States—as it exists to-day. During this period he was assisted in the business management, in planning the system of Mutual Water Companies—which system, by the way, the author to the contrary notwithstanding, the California Supreme Court, in the case of Thayer *vs.* California Development Company, has recently not only held to be legal, but has highly commended—and in making the tri-party contracts, by the writer and by Messrs. L. M. Holt (who with Mr. Chaffey evolved in 1881 the first Mutual Water Company ever incorporated, at Etiwanda, Cal.), N. W. Stowell (who was the first to introduce concrete water conduits to irrigation construction in California in 1878, and who had large experience with irrigation works), and J. W. Swanwick, who was largely responsible for the tri-party contracts.

A great deal has been stated in the public press and in governmental reports—and Mr. Mead in his discussion (p. 564*) might easily be understood by the careless reader as coinciding therewith—condemning the California Development Company as an irresponsible corporation at all times prior to the Southern Pacific Company's taking over the management in June, 1905. This was far from being true during the period when Mr. Chaffey was directing its affairs—April, 1900, to February, 1902. The men just mentioned were those he associated with him; all except the writer were unusually experienced in the different phases of irrigation work and development, and financially able to build the canal. Mr. Chaffey himself was a man of wide experience gained in the practice of his profession of Civil and Mechanical Engineer. Best known as the founder of Ontario, Cal. (1883), he had founded Etiwanda, Cal. (1881), and had developed the irrigation systems in both places to such a state that the visit of a Royal Commission from Australia in 1885, resulted in his proceeding with his brother to that country and establishing the irrigation dis-

* *Proceedings*, Am. Soc. C. E., for March, 1913.

Mr. Chaffey. tricts of Mildura and Renmark, both at this time populous and prosperous communities, conceded by all public men to be "the great object lesson in irrigation for the rest of Australia." In 1882 Mr. Chaffey produced the first electric current (generated by water-power) in Southern California, and in 1884 lighted the City of Los Angeles with electricity. A large number of the first settlers in the Imperial Valley were actually from Etiwanda and Ontario; all were experienced irrigationists, and it is safe to say that 90% of them made their purchases because they personally knew of Mr. Chaffey's previous successes.

The writer, of course, agrees with Mr. Mead that the State or Nation should protect settlers on and investors in irrigation projects, examine and approve engineering plans, etc., etc., and especially he agrees with his comments regarding water right laws, the unfortunate condition of which is responsible for most of the financial disasters which have overtaken irrigation enterprises in the West, and of which the California Development Company is, perhaps, the most notable example. At the same time, it must be admitted that the greatest and most rapid irrigation development the world has known is that responsible for what is known as Southern California, and the Government—State and National—in no wise helped and not seldom added severe handicaps. It is sometimes said that Southern California has been built on "shoe strings"—certainly, many most successful enterprises have been started with inadequate capital, on confidence in the proponent's resourcefulness. Under such conditions, people are "live wires" to a degree beyond the comprehension of officials and employees of powerful corporations and of the State and National Governments. Much of the resentment toward, and often unfair criticism of, private undertakings, by officials of the U. S. Reclamation Service, for instance, has its beginnings in the attitude of those who never need to consider for an instant financial arrangements, discounting securities, etc., toward "flimsy" work and the twists and turns of men driven to their wits' end when doing things with insufficient capital. It is well enough to say "Don't try them if you cannot get enough money to insure success." Such a policy would undoubtedly prevent not a few failures; but, on the other hand, by it the Southern California of to-day would not have been for decades to come.

The Imperial Valley is possibly the most striking example of this. In the first place, if the soil had been first examined by Government experts instead of by practical farmers, the project would have been condemned *in toto* and the region still original desert. Next, work was begun with small capital in hand, and in 10 months' time, and at the cost of less than $100 000, Mr. Chaffey put water into the burning desert 60 miles away from the Colorado River, and along lines, engineering, legal, and financial, which experience shows would have meant large success to all (had the Government only kept its hands

off), and by doing so realized the visions of the dreamers and the hopes of the promoters who for half a century had dreamed and promoted. and accomplished nothing. In less than 2 years, the Imperial Main Canal, essentially as it is to-day—except the $75 000 head-gate at Andrade—and more than 400 miles of distributing ditches, were completed and the water was ready to turn on to 100 000 acres of land, at a cost to the settlers averaging less than $10 an acre; and the cost was less than the promoters had expended in the hitherto vain effort to get started. Mr. Chaffey.

In contrast is the Government Yuma Project, with unlimited capital: $3 000 000 initial appropriation and more than $3 000 000 later; time, 8 years; acreage, 100 000; cost, $70 per acre; bitter disappointment and heavy loss to settlers relying on Government estimates as to money, and, more particularly, time required to complete the work. As a part of the Yuma Project, Imperial Valley would now be in exactly the state it actually was in 1902—eleven years ago—as far as development is concerned. In the meantime, in 1905, it was sending out $5 000 000 worth of products, and at present more than $10 000 000 worth. The gain in time has more than paid all the real damage *per se* done by the runaway river.

As the author has pointed out, this misfortune would never have occurred had it not been for numerous unnecessary and inexcusable obstacles. For some of these there is possibly some excuse, or at least explanation, but the soil survey and report was the most disastrous and inexcusable of all. The space devoted to it by the author in his paper is out of all proportion small compared to its significance, and the facts about it should be elaborated somewhat.

As stated by the author, a few samples of soil from this region were analyzed in 1893 by the Director of the California Experiment Station, University of California, Professor Hilgard, and again in 1896-97, and also in 1900, when the Imperial Land Company began active work. In the summer of 1901, the Bureau of Soils, U. S. Department of Agriculture, requested the co-operation of the promotion companies in making a study of and report on the soils of the Imperial Valley. This was gladly given, and, on October 17th, Mr. J. Garnett Holmes, of the Bureau staff, arrived and began work. Later, his immediate superior, Thomas H. Means, M. Am. Soc. C. E., and others of the Bureau, joined him, and on December 20th (in 63 days) the field work was completed. It took only 3 weeks (January 10th, 1902) to issue a preliminary report, "Circular No. 9," covering the 169 sq. miles of territory which had been examined. Before this circular reached California, an Associated Press dispatch from Washington advised that:

"The condition of soils in the Colorado Desert in San Diego County, as disclosed by a survey just completed by the Agricultural

Mr. Chaffey.

Department in the vicinity of the new irrigation plant at Imperial, is reported to be 'much more serious than was anticipated.' This is the expression used by Milton Whitney, Chief of the Bureau of Soils, in a preliminary bulletin which he has deemed best to issue by way of warning."

This refers to the report which the author says was "unfavorable, * * * and calculated to deter sensible people from settling in the region." This is a more than conservative way to put this matter, as is shown by the single extract—by no means the strongest of many—which the author quotes on page 1412.*

In 1903 the U. S. Department of Agriculture, Bureau of Soils, issued the "Soil Survey of the Imperial Area, California (Extending the Survey of 1901), Advance Sheets of Field Operations of the Bureau of Soils, 1903." This document, under the head of "Present and Prospective Development," on page 31, makes the statement:

"The sole dependence of the people of the Imperial Area must always be agriculture. * * * The source of wealth, therefore, is limited to the soil, and to a greater extent than in almost any other part of the country. Thus the problem confronting at least a part of the farmers in most arid regions is here—where alkali is so generally distributed in the soils and the conditions so unfavorable to reclamation—about as serious as it could well be.

* * * * * * *

"The people of the Imperial country should recognize the fact that aside from the general problem of securing water for irrigation they have to solve perhaps the most serious agricultural problem of the arid West. Here is found a most refractory soil, much of it impregnated with alkali. The only way to benefit the land is to carry away the salts. The application of gypsum cannot be of the slightest benefit. Little or no benefit will be derived from running water across the land with the expectation of flushing the alkali off the surface. * * * The water must pass through the soil and find ready egress through natural or artificial drainage ways.

"The quantity of salt taken out of the soil by alkali-resistant crops, such as sorghum and sugar beets, is not appreciable, the benefit to the soil in such cases resulting mainly from the prevention of evaporation at the surface through cultivation and from the leaching of the salts into the subsoil by irrigation water. If the subsoil be practically free from salt, as is often the case in arid regions, this vertical distribution of the salts alone is often all that is necessary so to reclaim the soil that sensitive crops can be grown. But it has been shown that in the Colorado desert the subsoil is the greatest source of danger, so that every bit of salt removed should be permanently removed. * * * By far the greater extent of the soil of the valley is a sticky, plastic loam or clay, through which water passes very slowly. The natural drainage in the soil itself is very poor, and to be anything like adequate it must be supplemented by artificial drains to carry off the ground

* *Proceedings*, Am. Soc. C. E., for November, 1912.

water as the salts are washed down from the surface. * * * Tile drains are the best and in the end the most economical for draining the land. They are, however, expensive, and the question is, will it pay? Mr. Chaffey.

* * * * * * *

"That it will eventually pay to drain these lands there can be little doubt, but in the present state of the country concerted action will be difficult and individual effort futile."

In February, 1902, the University of California, College of Agricultural Experiment Station, issued Bulletin No. 140, entitled "Lands of the Colorado Delta in the Salton Basin." This bulletin gave essentially the same results of soil analyses, but was much more careful in its comments, and on pages 50 and 51 gave crop reports from actual settlers which were excellent. It also stated, after giving a list of native plants from the Salton Basin, on page 44, as follows:

"The list of plants here given is notable for the absence of most of the species considered elsewhere as prominent alkali indicators. We miss at once the salt—or alkali—grass (*Distichlis*); the 'Greasewood' of Nevada (*Sarcobatus*) and that of the San Joaquin Valley (*Allenrolfea*); the samphire (*Saliscornea*); and the tussock-grass (*Sporobolus arioids*) * * *. But as a whole the collection made does not speak of 'irreclaimable' alkali land so far as we know their habits. * * * Taken as a whole, the native vegetation does not altogether confirm the unfavorable impression derived from the leaching of the soil samples."

In addition to these soil reports, in January, 1902, several interviews, written up in a sensational manner, appeared in the daily papers in California, practically condemning the Valley and virtually warning investors and settlers from the field. These were the most disastrous of all in their effect on the enterprise.

Experience has proved that these reports were fundamentally wrong in their conclusions, as less than one-half of 1% of the lands brought under cultivation has failed to produce most satisfactory, indeed, phenomenal crops. Nevertheless, the Government's publications were such that the author's statement: "It seems certain that, had the territory not been already settled in very large measure when these reports were sent out, Imperial Valley would yet be unreclaimed" (page 1412*), is undoubtedly absolutely true.

The author is in error on page 1406* in referring to the elevation of the bottom of the Chaffey head-gate. This structure was started in March, 1901, and work was rushed as rapidly as possible. When completed, its floor was 3 ft. below the river bottom, and, to make the gate more secure, three 2 by 12-in. sand-boards were put on the toe of the A-frame, to be removed when the sand and silt became settled

* *Proceedings*, Am. Soc. C. E., for November, 1912.

Mr. Chaffey. around the structure; there was no necessity for removing them while Mr. Chaffey was directing affairs, and, later everybody apparently forgot about them and they were never taken out, the idea thus obtaining that the floor of the gate was at the top of the sand-boards when in reality it was much lower, and as low as it was possible to place it that season. Working at high pressure against a rapidly rising river, the head-gate was finished, and Mr. Chaffey himself turned the water through it on May 14th, 1901.

Before leaving this subject, and in view of the controversy that has raged regarding the necessity of the fatal cut in Mexico (made more than 2 years after Mr. Chaffey had severed his connection with the Company), it is interesting to note, from Government records, that the old Imperial Canal, from the old intake, carried throughout the Summer of 1904 and until October, 1904, when the Mexican Intake was cut, more water than ever before, and quite enough to supply the users in Imperial Valley.*

The author's statement (p. 1396†) that the initial price charged for water stock was \$5.75 is misleading. Those who purchased during the construction period were given bonds of the California Development Company equal in amounts to their initial payments, bearing 5% interest and acceptable at their face value for the last installments on their notes. Hence, those paying \$3.00 cash on their water stock purchases got water rights at \$5.75 per acre. Only \$80 000, par value, of the bonds were thus given out to water stock purchasers on total sales of 50 000 shares in Imperial Water Companies Nos. 1 and 4, the settlers coming in having so little cash and speculators so little faith that they could not or would not take full advantage of the opportunity offered.

The author is again in error as to the reasons for the termination of the five-year construction contract between Mr. Chaffey and the California Development Company. It was not because the former was frightened out by the soil reports, but because it was found that the power of attorney to vote, for five years, stock, which, with his own, constituted a majority and control, was found ineffective on account of the certificates not having been actually turned over. Success had been achieved and these shares of stock began coming in for transfer. It became a matter of buy or sell, and the original promoter's idea of value was deemed to be too inflated, so Mr. Chaffey made the best terms possible for his holdings and withdrew in February, 1902.

The author's outline of the Delta Investment Company and its activities is also misleading, and in some respects entirely erroneous.

* See "Progress Report of Stream Measurements for the Calendar Year 1904," by the late W. B. Clapp, M. Am. Soc. C. E., Water Supply and Irrigation Paper No. 134, p. 27, and compare with measurements in previous years.

† *Proceedings*, Am. Soc. C. E., for November, 1912.

The facts are that in the fall of 1901 it became apparent that the sales of water stock would not produce sufficient money for the work that must be done, and Mr. Heber organized the Delta Investment Company in the hope that by giving it a favorable contract to purchase the bonds and mortgage notes of the California Development Company, outside capital could be attracted to the new company. The Delta Investment Company was launched with the consent and approval of those owning or representing all the stock of the California Development Company. By the terms of this contract, the Delta Investment Company agreed to purchase bonds and notes from the California Development Company to the amount of \$21 000 in cash per month for twelve months, thus guaranteeing the California Development Company \$252 000 in cash, the amount estimated as absolutely necessary to spend during the coming year in a permanent intake head-gate, canals, and other necessary works. In consideration of this guaranty the Delta Investment Company had the right for 12 months to purchase any or all of the bonds and mortgage notes of the California Development Company at 50% of their face value. Mr. Chaffey.

As the whole enterprise was still considered by outsiders as an experiment, and the banks of Los Angeles refused to concede any value whatever to the Company's "securities" for loaning purposes, or to purchase them outright at any figure at all, and the soil experts had commenced giving out their unfavorable opinions, the only reasonable criticism of this contract is that it was unfair to the Delta Investment Company and, consequently, unfair to those stockholders of the California Development Company who were large stockholders in the Delta Investment Company, in that it indirectly threw on them the burden of financing the California Development Company without adequate remuneration.

That the privilege of buying the bonds and mortgages at 50 cents on the dollar did not prove especially attractive is best shown by the fact that only a small fraction of the holdings of the California Development Company changed hands under it during the 4 months it was in operation. Mr. Cory, therefore, is correct in stating (p. 1402*): "It must be admitted that the Delta Investment Company took over such securities at a larger price than could have been obtained from any other source," but quite incorrect in stating either that there were many or "large" or "apparently dishonest" transactions between the two corporations, or in giving the impression that it was a hardship on the California Development Company to part with \$2 in its so-called "securities" for \$1 in hard cash. As a matter of fact, the California Development Company could well have afforded to be much more liberal, and the writer knows that if any one had come into the

* *Proceedings*, Am. Soc. C. E., for November, 1912.

Mr. Chaffey.

office at that time with $252 000 in gold coin and offered it in exchange for $1 000 000, face value, of the so-called "securities," there would not have been a voice raised against taking the money, it was so urgently needed.

Finally, the author is entirely mistaken in saying that March 1st of that year found the California Development Company "with all its bonds gone, its collateral notes and mortgages largely depleted, no money in the treasury, and deeply in debt." The facts are that it had $47 000 of its bonds on hand, $525 000 of mortgage notes, $235 000 of accounts receivable, besides lands, canals, machinery, equipment, etc., and unsold water stock estimated (at the selling price at that time) to be worth $2 235 000, and its liabilities, including $453 000 of bonds and deferred payments to Hanlon and Andrade, were less than $500 000; in truth, from a few months after Mr. Chaffey started work, the California Development Company never was without an ample supply of mortgage notes and bonds in the treasury, but outsiders had not sufficient faith in them to buy them for cash.

In view of what was accomplished in the 22 months ending February, 1902, and the fact that some of the best men in Los Angeles would have joined him and furnished large amounts of capital, provided he had secured full control, it is doubtless safe to say that had he taken control, instead of retiring from the company, there never would have been any runaway Colorado River and the development of the Valley would have been even much more rapid than it has been.

Mr. Grunsky.

C. E. Grunsky, M. Am. Soc. C. E. (by letter).—The problems of the Lower Colorado River have a wonderful charm. They are presented by Mr. Cory in a most comprehensive and attractive way, and he has done the Profession valuable service in putting on record and making available for convenient reference the results of an experience on river work which is unique in character and magnitude.

So long as there was a fighting chance, in 1906 and 1907, the engineers under Mr. Cory's guidance and upon the wise determination of Mr. Harriman were to keep up the fight. How the fight was won has been well told by Mr. Cory. The writer takes pleasure in again expressing his admiration of the able way in which the work was handled.

At the outset, every one, so far as the writer knows, believed that the work of making a closure in the fall of 1906 would be greatly facilitated by the use of brush mattresses on which to dump the rock. What the work done on the Colorado in 1906 and 1907 has clearly demonstrated is that, with adequate transportation facilities, a brush mattress on which to drop the rock is not essential. It is only necessary to place the rock more rapidly than the water can undermine and bury it.

Without the spur track from the Southern Pacific main line down to the Lower Mexican Heading, the first attempt to close the break would have been a failure, and yet the writer recollects distinctly that plans were under discussion for the beginning of this work, under which reliance was to be placed on water transportation. The outcome has demonstrated clearly that, when such work is to be done, every possible contingency should be foreseen so that every emergency can be met properly. It was a wise precaution, too, to keep an equipment and a force on hand and available for repairs during the high water of 1907, even though, as it turned out, they were not needed. Mr. Grunsky.

At that time the levees were new, and the river brought down an unprecedented volume of water—a maximum of about 100 000 sec-ft.* Naturally, it would be expected, therefore, that the levees had at once been subjected to a severe test. This might have been the case if the conditions on the lower river had remained as in years past; but they had been undergoing a rapid change, with the result that the new levee was only wet here and there, and there was no opportunity to observe what might have happened if the water had been 3 or 4 ft. up on the levee.

The writer made a special study of the problem of the Lower Colorado River for the Secretary of the Interior in the early summer of 1907, and his observations at that time and in the two preceding years as Consulting Engineer in the U. S. Reclamation Service, together with many years of familiarity with certain features of the river, are the basis of the comments which are now prompted by Mr. Cory's paper.

As early as 1883, or thereabouts, Gen. G. W. Shanklin, at one time State Surveyor General of California, and Mr. Duncan Beaumont called the writer's attention to the New River country, as a part of the Imperial Valley was then called, and the desirability of making an instrumental survey to see what could be done toward accomplishing the irrigation of that valley was discussed. It was known at that time that the only practicable route for a canal would be across Mexican territory. The situation appeared to be too complicated, and nothing was done; but the writer, from that day to this, has never lost interest in the problem.

In 1896 the writer explored a portion of the Colorado River below the Grand Canyon and confirmed the selection of a dam site at the lower end of Iceberg Canyon, as the best available, in a long stretch of river, for a low dam to be used in creating a fall for power. He reported at that time that it would be feasible to construct a dam of loose rock on a sand foundation by blanketing the bed of the river for a considerable distance up and down stream with broken rock, using large blocks for the down-stream portions of the work, allowing

* Erroneously estimated at 115 000 sec-ft. by the U. S. Geological Survey in Water Supply Paper No. 249.

Mr. Grunsky. the water to bury these as deep as it would, and using finer material in the up-stream face, which would ultimately be made impervious or nearly so by the river silt. The plan of that day involved the complete turning of the Colorado over a low spur of the mountains. Mr. Cory's experience at the Lower Mexican Heading confirms the feasibility of carrying out work of this character.

Several years later the writer was stationed for three months on the Colorado a few miles above the mouth of the Virgin River, and had additional opportunity for observation. At that time boilers were to be set for mining operations, and brick was wanted. No clay deposit could be found. The most promising mud-bar in the river was sampled. The mud could be balled up and would crack somewhat in drying. It was submitted to a chemist at San Francisco and reported to be composed almost entirely of very fine silicious sand entirely unfit for brick-making.

Above the Virgin River the water of the Colorado, at low and high stages, carried a large quantity of this silt in suspension. This would settle quickly when the water was dipped from the river in a glass, and within a few seconds the water was clear enough to drink. There was certainly comparatively little clay in the silt carried by the river water at this point. This observation leads the writer to assume that the main Colorado must be the principal source of the fine, light sediment, other than clay, which the river carries to the delta, and accounts, too, for the preponderance of material of this character in the river delta; it also makes it appear probable that the clays, bedded as the author describes, probably have originated in other parts of the river's water-shed.

During the low stage of the river, above the Virgin, the writer had occasion to erect a mast or pole on a gravel bar for the support of a cable. The gravel was unusually firm. It consisted of all sizes from cobble-stones down to sand, and in its dry condition appeared to be almost cemented. The mast was erected and large boulders were piled around it. When the river rose the gravel around the mast became wet, softened, lost its cohesion, and acted very much like a quicksand; the mast required additional support or it would have fallen.

A heavy crankshaft lying above the water on another portion of the gravel bar commenced to sink into the gravel when this was wet by the rising water, and was with difficulty supported until it could be transferred to safer ground.

These facts are alluded to as a warning against placing too much reliance on gravel for the facing of bank or levee slopes. The gravel, in the case of the Colorado River levee, serves a most excellent purpose, and its use is not criticized, but gravel has no particular virtue as a material for resisting the attack of a current, and will have but little resisting power when used in spur dikes. It is an excellent

material, however, as in the case of the levees on the Mexican side of the Colorado, for blanketing the levee, serving as a protection for the earth slope against wind erosion, and checking to a large extent the activities of burrowing animals. Mr. Grunsky.

The Colorado below Yuma, as explained by Mr. Cory and as noted by the writer in a paper presented to this Society in 1907, is flowing down the slope of a delta cone. While undisturbed by human agency its floods annually watered broad areas, and the rank vegetation which sprang up on these areas was an effective barrier opposed by Nature to the concentration of the river's flow along new channels, even though some of the water going over-bank should long ago, if topography alone is considered, have cut out a new course for the river. The river has been compelled by these restraining forces to hold for more than 500 years to the course as geographers first knew it from Yuma to the Gulf.* However, though the river, unaided, could not break away from this general alignment, it swung back and forth, within restricted limits, on an ever-changing serpentine course. The river along the thread of the stream has a fall of about 1 ft. per mile, and the average fall along the air line from Pilot Knob to the Gulf is about 1½ ft. per mile.

When attempts are made to confine a river of this character between levees there is trouble. Under the attack of the river, the banks will continue to break away, first at one point and then at another, and no amount of care in the location and construction of levees can insure them against destruction from this cause. To check the caving bank is difficult and expensive, even when adequate facilities are at command, as has been well set forth by Mr. Sellew. In ordinary cases, it is out of the question to eliminate entirely this source of danger to levees located comparatively near the river bank.

It is natural, then, that the levees in the case of such a river should be set far back from the banks. In this location on the Colorado the levee cuts off the river bends and, therefore, follows a line of greater slope than the river. This is actually the case below Yuma, except for the first long stretch below Pilot Knob, where the river is straight for some 8 miles and the levees on each side are parallel with the stream and comparatively near the banks. Below this straight reach, the river channel, down to the Arizona boundary, is about 30 or 40% longer than the levees on their present location (Plate L).†

If the river rises above banks and water stands against these levees, some barrier must be interposed to its flow if erosion at the base of the levee is to be prevented.

Even when constructed as was the original levee at the Lower Mexican Heading, with borrow-pits on the land side, the work of levee

* *Transactions*, Am. Soc. C. E., Vol. LIX, p. 6.

† *Proceedings*, Am. Soc. C. E., March, 1913.

Mr. Grunsky. building gives more or less open space for the water on the river side along the levee, and there will be concentration of flow there which will rapidly cut channels in the light silt soil of the delta. The spur dikes, as built by Mr. Cory, offer some obstruction to this flow, and are of value under certain conditions; they have been of use during such moderate bank submersions as have occurred since the levee was built, but under a real test, with water 4 or 5 ft. on the bank, they would serve to concentrate fall and would start local cutting which might prove quite as dangerous as the general erosion due to uniform flow along the levee. It may be stated in a general way that the efficiency of such spurs for the same aggregate quantity of material in them will ordinarily increase as distance between them is decreased.

While Consulting Engineer in the U. S. Reclamation Service and adviser to the Secretary of the Interior, the writer reached the conclusion that it would be hopeless to endeavor to carry out the proposed scheme of building levees along the Gila River just above Yuma. Levees along the banks of the Gila cannot be maintained short of an expenditure for bank revetment which the value of all the land to be there protected would not justify. The situation is somewhat more favorable on the Colorado, which, owing to a lighter gradient, is less erratic than the Gila, but there, also, the fact should be recognized that it presents no ordinary problem.

The land to be protected on the Lower Colorado is of such extent and of such fertility and potential value that there should be no hesitancy in taking every step that may be necessary to bring the Colorado under permanent control.

The Secretary of the Interior was advised by the writer in 1907 that the Colorado should be given permanent banks from Pilot Knob about as far down as the Arizona boundary. He was advised that this work might cost from \$50 000 to \$150 000 per mile of bank, involving, as it would, permanent loose rock revetment of banks; and that the United States should be prepared for an expenditure of from \$4 000 000 to \$5 000 000, of which a portion should be contributed by Mexico because the benefits of the work would accrue to Mexico as well as to the United States. He was also advised that there should be created at once an International Engineering Commission, with full power to undertake the work of giving the river a permanent direct channel, as indicated, and to give consideration to all other problems arising on this stream. At the same time, the irrigation problems were reviewed, and the need of an early action for the protection of the Imperial Valley was pointed out.

At that time the Imperial Valley had to depend on a foreign corporation, *La Sociedad de Yrrigacion y Terrenos de la Baja California,* for protection against overflow and against complete and permanent submersion of the valley by the Colorado. It had to depend on

this company, and it is still dependent thereon, for its irrigation water, which, after being diverted from the river in the United States, is turned over to the Mexican Company by which it is re-delivered into California. Such an arrangement needs the sanction and protection of higher authority. The arrangement cannot be regarded as entirely satisfactory until, under some treaty or other convention with Mexico, the right of a diversion of Colorado River water through Mexico is permanently assured to the people of the United States, and the two countries acting in harmony adopt adequate measures for keeping the Colorado out of Salton Basin. Mr. Grunsky.

Circumstances have favored the maintenance of the work done on both sides of the Colorado prior to 1907 below Pilot Knob. In that year the river carried more than the ordinary quantity of water; but the delta had been dry for two seasons, the river banks were free of grass and weeds, which had been largely burned off, and the over-bank flow, therefore, was far in excess of what would have occurred if the river had not been out of its natural course from 1905 to 1907, and if well-watered banks had been covered with dense vegetation. Due to its bare banks and to the consequent large over-bank flow at low elevation, the river did not rise as high and there was not as much water against the levees as there might otherwise have been. Then, too, in the spring of 1907, the cutting off of Nigger Bend and the shortening of the channel at that point by 2 or 3 miles had some effect in lowering the high water as far up stream as Yuma, and then—in 1909—came the relief at the Abejas. It may be assumed, therefore, that the behavior of the levees on both sides of the river, in 1907 and in the following seasons, is not a conclusive test of similar structures.

The writer inspected the levees on both sides of the river at high water in 1907. On the west side the levee below the dams at the Lower Mexican Heading had not been wet. At and near these two dams, completed a few months before by Mr. Cory, where the borrow-pits were on the land side, there was some seepage under the levees. Miniature, pin-head, under-water volcanoes made this apparent to the eye. The water in the borrow-pits was but little lower than in the river, consequently this seepage was caused by a pressure head of only a few feet. No doubt, it would have increased somewhat with a rise in the river. It was the result of the slow movement of the soil-water inland from the river.

On the Arizona side the borrow-pits were carrying a small quantity of water; they were not bank full. The abattis work across the borrow-pits appeared to be catching considerable trash, and each barrier of this kind checked in some measure the velocity of flow for a short distance up stream, but gave the impression that under ordinary conditions of bank submersion such structures would have been quickly cut out by the water passing around their ends. The writer was not

Mr. Grunsky. impressed with their efficiency, although they undoubtedly did some good under the conditions which prevailed in 1907.

In 1910 the writer again had an opportunity to inspect the levee on the west side of the Colorado, and noted that where the checkerboard arrangement of borrow-pits had been adopted the spill from one into the next, even with very slight river bank submersion, had caused some channel cutting, making clearly apparent an inherent weakness of this arrangement.

After a number of favorable seasons these outside borrow-pits will to a large extent be refilled with sediment from the river. If located close to the bank and on no greater slope than the river, the refilling of such pits along such a river as the Colorado may occur quite rapidly. Until thus refilled and overgrown with vegetation, they are, to almost the same extent as a continuous borrow-pit, a menace to the integrity of the levee whenever the latter follows an alignment along which there is an excessive fall, as is the case on the Colorado with the Paredones levee and with those above and below the Abejas.

In reporting to the Secretary of the Interior on the matter of river treatment, the desirability of using hydraulic dredges in the construction of the levees was referred to by the writer, and he still believes that, wherever the location will permit, the bulk of the levee work on the Colorado should be done by this method. The first work would then be the excavation of an ample trench, the material from which would form the river side restraining embankment for the hydraulic fill. The hydraulic fill would then be deposited in the rear of this, refilling the trench and bringing up to the desired height an embankment so wide of base that underflow through cracked soil and through burrows would be made impossible.

The writer is of the opinion that the control of the Colorado between permanently fixed banks should not be projected beyond some agreed point near the Arizona boundary line. If the river is kept on a proper alignment down to that point, it can wander about over a large lower portion of the delta without menace to the Imperial Valley. It will then, as it does to-day, send its waters, at least in large part, into the Volcano Lake region, and will warp up first one and then another section of its lower delta region. In the far future, then, the time may come when complete control to the Gulf can be economically justified.

If controlled mainly by giving the river a direct alignment between permanent, well-protected banks, supplemented with levees, as far down stream as here indicated, the protection of the Imperial Valley and the whole Alamo and New River country will be complete, if the cross-levee to the northward of Volcano Lake from the base of the Cocopah Mountains to the Colorado at the Lower Mexican Heading

and up the river to Pilot Knob be brought up to proper height and be protected adequately, particularly against wave action. Mr. Grunsky.

The writer desires to note that the various estimates of flow of the Colorado, even those based on gaugings, are to be accepted with caution. Some additional information relating to methods of gauging should be given before these estimates are accepted as conclusive. This applies particularly to the measurements made at the river's high stages. It is understood that some special precautions are now being taken to insure accuracy of soundings and the correct placing of the current meter at the intended depth; but in 1907 the writer knows that this was not done, and that the maxima then recorded are too great by from 15 to 20 per cent.

The two-point method of gauging was at that time used. The gauging was made from a car supported by a cable. In mid-stream the car was from 5 to 8 ft. above the water surface. A sounding was made immediately before the velocity was measured. The heavy sounding lead was lowered from the car to the water surface and a reading of the paid-out line was taken. Then it was lowered to the bottom of the river and another reading was taken, the difference between the two being recorded as the depth. No allowance was made for the line swinging out of the vertical, due to the force of the current, which was about 7 ft. per sec. in mid-stream. By observation from shore on June 24th, 1907, the correction to be applied to the recorded mid-stream depth of 45 ft. was found to be about 6 ft. The recorded depth determined the required immersion of the current meter. When the meter was supposed to be at one-fifth depth, or 9 ft. below the surface, it was in reality barely below the surface; and when it was supposed to be at four-fifths depth, it was but little deeper. The only value of the velocity measurements as made lies in the fact that they can be used to determine surface velocity. They were recorded, however, as applying to the two-fifths and four-fifths points, with a resulting over-estimate of mean velocity. In this particular case the recorded discharge should be reduced 15% to give approximately the flow of the river on that day.

The errors of observation as above noted were, of course, called to the attention of the Reclamation Service and the United States Geological Survey, but no correction has been applied, and the writer does not know how long such methods of gauging were maintained at that station.

In Water Supply Paper No. 249 of the U. S. Geological Survey, page 45, the discharge is noted for June 24th, 1907, at 112 000 sec-ft. Of this quantity 11 000 sec-ft. were flowing in the north channel of the river and 101 000 sec-ft. were recorded for the main stream. According to a proper interpretation of the measurements on that day, the main stream carried only 86 000 sec-ft., and probably somewhat

Mr. Grunsky.

less. The aggregate discharge for that day should have been noted at 97 000 sec-ft., instead of 112 000 sec-ft. The error in the main stream gauging was about 17%, or the recorded main stream flow should be reduced 15 per cent. The same correction should undoubtedly apply to the entire period in 1907 during which the river was at or near its highest stage. The writer has no information as to whether the same method of gauging was still in use in 1909. If it was, there can be no doubt that in that year, also, there must have been a considerable over-estimate of discharge.

Mr. Cory is right in his conclusion that the construction of reservoirs within the water-shed of the Colorado will have some beneficial effect in equalizing the stream flow and in reducing the maximum discharge. It is immaterial whether or not the storage possibilities have been over-estimated. This can only affect the extent of the reservoir influence; and yet, whatever this may be, it will not change the river problem, except as to its magnitude. The river will still have its varying volume of flow. Its channel will adjust itself to the new conditions. The same lack of channel capacity will be felt at high stages on the lower river as is felt to-day, and the same problem of keeping the delta channels of the river on the Gulf slope will confront the river engineers of the future as confronts those of to-day, except only that there will be somewhat less water and correspondingly less silt to be reckoned with.

Perhaps a word should be said about the Laguna Weir. The change in the original design from a paving with large blocks of rock to a paving with concrete was due to the fact that the granite which had to be removed at each end for the sluice-ways was not of a character which could be used for this paving work. It was anticipated by the engineers who designed and approved the structure that the granite at the "Lagunas" which appeared to be disintegrated and rotten at the exposed surface would be of good quality when cut into; but, as the work progressed, it was found that the hills afforded very little sound rock within the limits of the prescribed excavation, and that at the best quarry sites near the weir only a small proportion of the rock was suitable for paving. This situation was carefully considered before a modification of plans was recommended by the Board of Consulting Engineers which had this matter under consideration in 1906.

The writer, though not desiring to criticize unfavorably the works which have been carried out at Laguna for the diversion of water into two canals, one on each side of the river, has never been in full accord with the general arrangement of the structures at that point. The plans for these structures were approved before he had anything to do with the Reclamation Service, and no one is more pleased to learn that they are rendering satisfactory service. Nevertheless, he

would call attention to the fact that the decrease of depth of overflow over such a structure, resulting from its great crest length, 4 700 ft., is not necessarily of sufficient importance to outweigh the disadvantages that will result from the use of a dam with so long an overfall crest. The storage of silt in the reservoir space above the dam, in the case of such a river as the Colorado, is of no importance. This space, except for a channel of ordinary width leading to the sluice-gates, is soon filled with silt and overgrown with willows and cottonwoods. There is a strong tendency for drift to lodge, and, within a few years, there may be such obstruction to a concentrated flow in lines parallel to the original course of the river that it may be difficult to keep the waterways open to the two ends of the weir without permitting one or the other to parallel and endanger the structure. The conditions at the weir, in a few years, may be such that water will go over it at uneven depth, and, in that event, the great length will fail to accomplish fully the desired purpose. At any rate, there will be trouble from time to time in keeping the water on a proper course to the two ends of the dam. The removal of silt which the sluice-gates will permit is dependent on the depth of the sluice-ways below the sills of the canals. The silt which the river will deposit in the large channel leading to a sluice-way, while the water is forced to rise to the crest of the dam, can of course be sluiced out from time to time by opening the gates, but this will be restricted to the deposit in a channel. It is not the accumulation in a reservoir, and this fact should not be lost sight of in planning such structures. Even this, however, may be worth while. The writer believes that the river should have been forced into a definite position above the weir by making a section thereof, probably 800 ft., a few feet lower than the rest of the structure and then arranging flanking walls to be overtopped at highest stages of the river and to serve as training walls of the large-capacity channels leading to the sluice-gates, which would, as at present, serve to keep the channel open to the head-gates. One great advantage of such an arrangement would be the concentration and depth of flow necessary to carry drift of whatever size over the dam. Mr. Grunsky.

Clarence K. Clarke, Esq.* (by letter).—Although this paper and Mr. Sellew's discussion of some phases of the subject seem to have covered the ground quite thoroughly, it appears to the writer that room remains for a few statements of fact concerning the "rough and ready methods" of dealing with the river which Mr. Sellew does not accept as a solution of the engineering problems pertaining to the subject. Mr. Clarke.

Being one of the men referred to by Mr. Sellew as "red-blooded fighters, who did not know when they were whipped, but * * *

* Chf. Engr., Palo Verde Mutual Water Co.

Mr. Clarke. fought on to victory unmindful of its cost," the writer desires to correct an erroneous impression. The crevasse in the river bank and levee in 1907 was closed by railroad men, who used methods with which they were familiar; they tried no experiments and devised no new engineering practice. They knew they were not whipped at any stage of the game, and they kept at the job because they had done the same thing on a smaller scale many times and were confident of ultimate success.

The use of the water of the Colorado for the irrigation of land creates the problem of control. There is no other reason for subjecting that river to control. The problem, so-called, as the writer sees it, presents three phases: 1, direction of the flow of the river and control of its meanders, involving bank protection; 2, exclusion of overflow water, by levees, from land susceptible of reclamation and irrigation; 3, safe and certain diversion of water from the river into irrigation canals.

The Lower Colorado has no fixed channel, because of the character of the soil, which is a deposit of silt, readily eroded. The current swings back and forth, cutting the banks and changing the meander line, and an apparently insignificant obstruction sometimes causes shifting of the channel for miles. A sudden shift of the channel from one bank to the other may leave a canal intake dry and put an irrigation system out of business. It may cut across a tongue of land, changing a wide bend into a tangent and forming a new bend lower down. Therefore, one factor of the problem is the maintenance of a defined course of the river between permanent banks. That may be accomplished by adequate protection of the banks and control of the meanders. It is advisable and feasible to straighten the course of the river at some points, and by increasing its velocity, to check its tendency to swing from side to side. The shortening of the river, resulting from the elimination of many horse-shoe bends, would increase the scouring action of floods and their silt-carrying capacity, and greater volumes of sand and silt would be transported to the lower delta and deposited there, building up large areas of land and accelerating the work that the river has been doing for ages. By the control of the lower river, the floods could be diverted into the basin of the Laguna Salada, and that shallow basin could be converted by silt deposit into an arable and fertile valley. In time, of course, the deposition of silt would work back, and the normal grade of the river would be re-established, necessitating the adaptation of levees to the new condition.

It is the writer's purpose to point out that this is not a problem calling for the invention of new methods of river control.

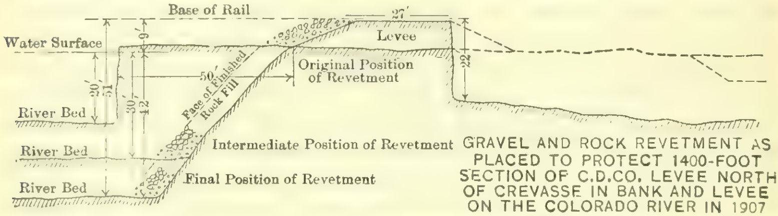
Bank Revetment.—Effective bank protection can be provided most readily and economically by laying a railroad track on the top of a

levee; and, as other writers have suggested, it may be applied in sections as needed. That tracks on the levees along the Lower Colorado are indispensable to their maintenance and the defence of the banks against undercutting attacks by the river, has been the writer's fixed conviction since his first experience with the river, and he notes with gratification that Mr. Sellew has revised his former opinion on the subject and concluded that the railroad track facilitates the work of levee protection to a degree that more than offsets the cheapness of the methods heretofore used by the Reclamation Service on the Colorado. Mr. Clarke.

Having the "firing line" established by the track on the levee, it is important to provide an abundant supply of "ammunition" and means of rushing it to "the front." Quarries and gravel pits are opened, and are equipped with derricks to handle large rock, and steam shovels to handle small rock and gravel. When the river begins bank cutting and threatents to undercut the levee, train loads of gravel and rock are taken to the point of attack and dumped at the toe of the levee. Gravel is dumped first in order that it may underlie the heavy rock and prevent the sluicing out of silt and sand where the rock lies on the bottom. When the bank caves, the rock on the berm falls into the trench dredged for it by the river, and if the scouring continues and the trench is deepened, more rock is dumped to reinforce the revetment and raise it to the crest of the levee. Small rock and steam-shovel material serve to fill and face the revetment. When such revetment has dropped to the river's lower scour plane and has been completed by proper reinforcement, the work of bank protection at that point is done permanently, and the levee thenceforth is safe from undercutting.

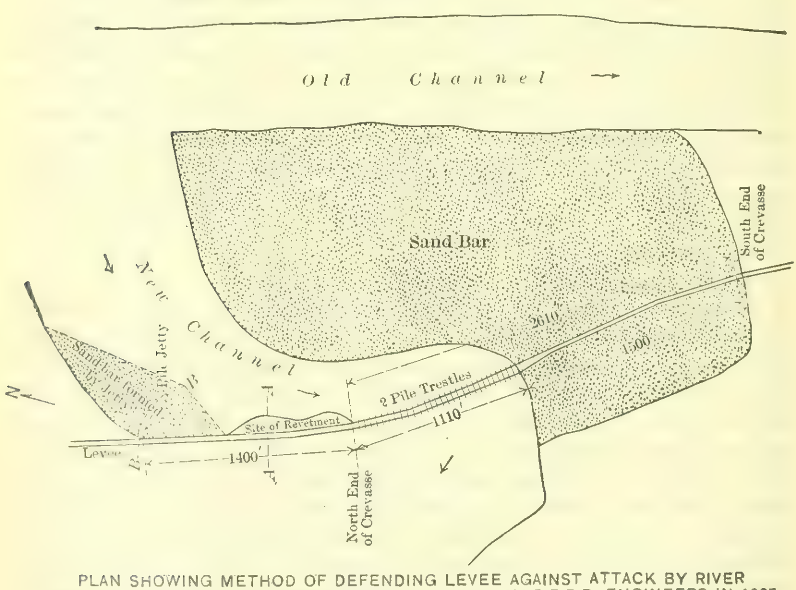
An illustration of this method of bank revetment was the saving of a section of the C. D. Co. levee, as a part of the work of closing the break with what Mr. Cory calls the Clarke Dam, in January, 1907. The river swung in against the levee north of the break and threatened to destroy 1 400 ft. of the embankment and widen the crevasse from 2 600 to 4 000 ft. The width of the berm between the toe of the levee and the bank varied from 30 to 50 ft. for the greater part of the 1 400 ft., but near the north end of the section the current had washed away most of the berm, and in the bight the water was close to the toe of the levee. To divert the current from this bight, a jetty 90 ft. long was built out from the upper side. The jetty consisted of two rows of piling, 5 ft. between rows and 8 ft. between piles in the row, the piles being "staggered" or alternated. The piles were 40 ft. long, and were driven in 26 ft. of water. Before the completion of the jetty, the discharge of the river was increased to 40 000 sec-ft. by a freshet in the Gila. Gila freshets carry great volumes of heavy silt in suspension, and this material drops readily when the velocity of the current is checked. It was not necessary to oppose any other barrier or baffle

Mr. Clarke. than the piles to this heavily laden flood, and no brush was placed in the jetty. Eight days after the completion of the jetty, the river discharge fell to 15 000 sec-ft., and a bar was exposed on each side of the jetty and extending 13½ ft. beyond its outer end, where the water had been 26 ft. deep. The rapid formation of the bar was due to the Gila silt. To accomplish similar results with Colorado River water alone, more obstruction, in the form of fascines or wire entanglements, would be required, and the process of bar formation would be slower.



SECTION ON *A-A*

FIG. 41.

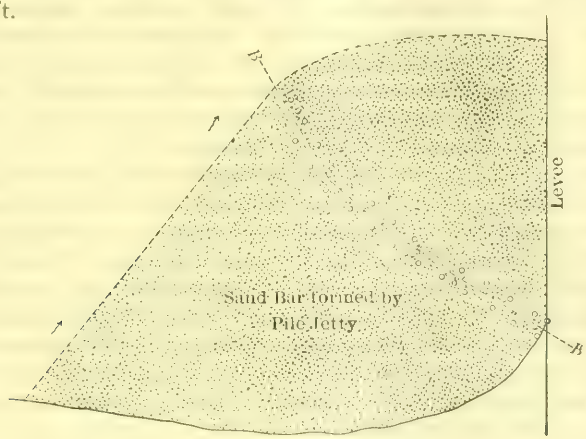


PLAN SHOWING METHOD OF DEFENDING LEVEE AGAINST ATTACK BY RIVER DURING CLOSURE OF COLORADO RIVER CREVASSE BY S.P.R.R. ENGINEERS IN 1907

FIG. 42.

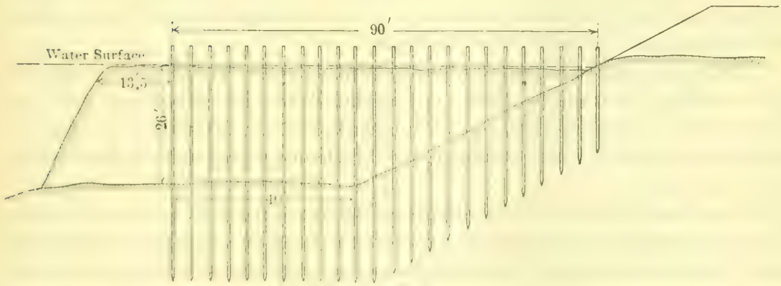
When the jetty was built, the levee embankment was widened toward the river with gravel and rock, the track was moved to the extended fill, and large quantities of gravel and rock were unloaded, covering the berm to a width of from 8 to 10 ft. from the toe of the

levee. As the river cut away the bank and deposited the gravel and rock at the bottom, where the material was needed, more rock was unloaded. The depth of water at the bank, when the cutting began, was from 20 to 25 ft. This depth increased to 42 ft. as the river dredged a trench, and at that depth the scouring action ceased. When the revetment was completed and the 1 400-ft. section of levee had been protected, the height from river bottom to base of rail on the levee was 51 ft. Mr. Clarke.



PLAN OF PILE JETTY

FIG. 43.



SECTION ON B-B

SECTION OF SAND-BAR FORMED BY PILE JETTY FROM C.D.LEVEE ON THE COLORADO RIVER, 1907

FIG. 44.

Gravel is a factor of vital importance in this method of placing rock on a sand or silt bottom, a detail which appears to have escaped the notice of some of the "innocent bystanders," who watched the closure of the crevasse and predicted utter failure of the work. The plan of providing revetment material at a threatened point and leaving to the river the work of dredging a trench and placing the rock, has been approved recently in a practical way by so eminent a river engi-

Mr. Clarke. neer as Mr. Sellew, who used the method last year in defending one of his levees from attack. As he does not refer to the use of gravel as a bed for rock revetment, presumably that essential detail of the method was omitted.

This method of bank protection, however, is no innovation, and, in his application to the closure of the Colorado crevasse of practice that is old to "firing-line" railroad engineers in the West, the writer cannot lay claim to originality. He used the same method on the San Pedro River, between Benson and Fairbank, in Arizona, many years ago. In 1891, the roadbed of the Northern Pacific along the Puyallup River, in Washington, was protected in identically the same way within less than 4 miles of the Tacoma depot, where doubtless many "innocent bystanders" observed the work.

Control of the River.—The general application of this system of revetment to the banks of the Lower Colorado, in the writer's opinion, would solve, simply and at comparatively low cost, the problem of keeping the river within defined bounds and protecting levees against undercutting between flood seasons. Combined with the straightening and shortening of the river's course and control of the meanders, this revetment of banks would increase the efficiency of the channel. Trees and other obstructive growth on the bars and flats would be removed by the river itself, and its carrying capacity would be sufficient eventually to take care of floods.

Experience has demonstrated that the revetment here described, consisting of gravel and rock, and placed from the lowest scour plane to the crest of the levee, constitutes a permanent barrier and solves the problem of control of the Colorado.

The resulting rock-reveted permanent barrier would be similar in all essential features to that contemplated in the suggested plan of river control attributed to Gen. Marshall, which involves the excavation of a trench to the ascertained scour line by the use of dredges or power shovels.

A serious objection to the suggested plan referred to is that it would be applied without reference to immediate need for defense, and would entail large expenditure for dredging and revetment where protection might not be required for many years. The cost of excavating trenches to the scour line, along both banks of the Lower Colorado, with dredges, would be enormous, and it has been demonstrated that such expenditure is quite unnecessary. The river can be depended on to do all the dredging and to place the gravel and rock at the bottom of the trench.

Only the National Government could or should undertake the task of controlling the Colorado, as it has prosecuted the work of protecting lands along the Mississippi against inundation. The first step in the project obviously would be to construct levees along both banks

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and lay tracks thereon. During the progress of this work, gravel and rock quarries should be opened and equipped with the requisite loading appliances, and cars should be provided to carry the material to the front. In case of attack on the levees by the river, material would be sent to the threatened points, and the work of permanent revetment would be done at those points. After the completion of the levees, the means and material for revetment would be kept in readiness; during each flood season the river would be observed vigilantly; and every attack on the levees would be met promptly.

This method would distribute the work over many years. Conceivably, 50 years or more might pass before the banks would be reveted throughout the course of the lower river, but during that time the stream would be virtually under control. The cost also would be distributed, and no very great expenditure probably would be called for in any one season. The ultimate result would be absolute control of the river between permanent barriers defining its course.

Control of Meanders.—Emergency methods of control of meanders and of the direction of the channel, used on the Colorado, are simple and comparatively inexpensive, and may be applied by settlers to the temporary protection of their riparian lands. The writer had occasion to resort to these methods in January, 1913, for preservation of the flow of water through the intake of the Palo Verde Valley irrigation system.

The Palo Verde intake is cut through a rock projection into the lower part of a wide bend in the river. The river developed a tendency to cut across the bend by the chord of the meander arc, and, if unchecked, the channel would shift toward the Arizona shore, and leave a wide bar in front of the intake. This tendency was shown in the cutting away of the nose of a bar that extended from the Arizona or eastern shore to about the middle of the bend, and it was necessary that the bar should be maintained. This was accomplished by driving posts and placing fascines and sand bags on the point of the bar. A fascine jetty was built out from the Arizona bank, 1½ miles above the bar, and pointing down stream at an angle which would direct the current into the bend above the intake. The cost of this work was small, and the effect was all that was required. The channel was kept in the bend close to shore, and the supply of water through the intake was assured for the season.

By similar means, when the river begins cutting the bank and threatening destruction to lands or levees, a bank-caving current may be converted readily into a silt-depositing eddy. Fascine jetties—rows of driven posts with bundles of brush placed between them and anchored with sand bags—may be built quickly by the farmers, and danger may be averted if detected early and if the remedy be applied at the first indication of trouble. Such temporary defences are avail-

Mr. Clarke. able in advance of the permanent system of protection, consisting of levees, railroad tracks, and rock revetment, and may be built by intelligent farmers without the aid of engineers.

Levee Construction.—The writer did not participate in the exhaustive discussion of the relative merits of river-side and land-side borrow-pits in levee construction on the Colorado, which followed the failure of Col. Ockerson's levees and was carried on recently by many engineers in the technical press. The subject having been reopened by Mr. Cory and Mr. Sellew, however, it seems pertinent to call attention to a few facts which have been overlooked or ignored by both.

Mr. Cory explains clearly and correctly the failure of the levee below the Hind Dam in December, 1906, which was due solely to the absence of a muck-ditch under the levee. He gives reasons for the omission of the muck-ditch, chief of which was the supposed necessity for confining expenditure, as closely as possible, to the repair of the break. Mr. Cory says the desirability of muck-ditching was fully realized, and it was a part of the original design, but because levees had been built without muck-ditches on the Colorado, and some one advanced the theory that a cracked adobe foundation would be made tight by pressure when wet, the vital necessity of muck-ditching was not recognized, and the builders of the levee decided to "take a chance." The theory of the closing of adobe cracks proved unsound. Water followed the cracks under the levee and caused the break.

Mr. Sellew admits that water did go under the levee because of the absence of a muck-ditch, but he contends that "the damage caused by a head of 15 in. against the levee was due primarily to the presence of land-side borrow-pits."

The borrow-pits, 3 ft. deep, were separated from the levee by a berm 40 ft. wide, and it is manifestly absurd to assert that there could be any relation between the pits and a 15-in. head against the levee. The pressure angle of the greatest head against any levee on the river would not reach the pit. According to Mr. Sellew's theory, an inside borrow-pit ½ mile back of the levee would increase the static head and cause failure of the work. Mr. Cory left an opening for attack when he said the increased total head was "the only pertinent objection to land-side borrow-pits." Experience has demonstrated, however, that the objection is impertinent, irrelevant, and immaterial. No land-side borrow-pit levee, properly muck-ditched, on the Colorado, has been broken or even damaged by the river, but every river-side borrow-pit levee has been breached or destroyed, and every flood season since levees were first built on the river has seen a strenuous fight to maintain them. The river-side borrow-pits are invitations to the river to side-wipe the levees with currents of eroding velocity, and a levee not blanketed heavily with gravel, or rip-rapped with rock or mattresses, melts away like a bank of salt. Every levee breach has been

caused by current erosion, not by static head or pressure. No levee has been pushed over by the river. Mr. Clarke.

"Last Word" on Borrow-Pits.—Quoting from Mr. Sellew's discussion, page 543*:

"Regarding the advantages and disadvantages of land-side and river-side borrow-pits, the writer has fully expressed himself, so that it is not necessary to comment further. Particularly is this so when the author [Mr. Cory] states that he 'realized that this [land-side borrow-pits] was not in accordance with the usual practice.'"

The implication that Mr. Cory confessed judgment against the land-side borrow-pit and yielded every point to Mr. Sellew in the argument, seems to the writer no more than a verbal quibble. A practice may be "usual" and still not the best possible under all conditions.

Doubtless there is satisfaction in the belief that one has routed all opponents in argument and said the last word on a debated subject, but it does not appear to the writer that any one of the eminent engineers engaged in the borrow-pit discussion has warrant for "laying that flattering unction to his soul."

It might be inferred from Mr. Cory's statement, that the land-side borrow-pit method of constructing the C. D. Co. levees in 1906-07 was "decided on after careful consideration of the advantages and disadvantages," that there was doubt on the subject in the minds of the men on the job. The matter may have been—in fact was—debated persistently by the "innocent bystanders," but there never was any question of methods in the minds of the railroad "firing-line" engineers having direct charge of construction. It is and has been for years, not only the usual practice, but the invariable rule of railroad engineers in the West, that nothing between an embankment and a river shall be disturbed. The protection afforded by earth in place and by trees and brush must be maintained intact. That was why the land-side borrow-pit system of construction was adopted as a matter of course. It was followed until the bystanders, tired perhaps of being innocent, got themselves appointed as a "consulting board" and after two attempts succeeded in getting an imperative order from financial headquarters to the engineers on the job to conform to the usual practice of the levee builders on the Yuma Project. Had they succeeded earlier, the levee could not have been built at all during the flood period. From the moment the water came over the river bank, work of any sort on the river side of the levees was impossible.

Experience in railroad construction and maintenance in regions subject to floods, in the building of dams and levees in the Delta of the Colorado and in the Palo Verde Valley, and in the control and maintenance of irrigation canals of large capacity, has left the writer in no doubt concerning the essential principles of levee construction on the Lower Colorado River.

* *Proceedings*, Am. Soc. C. E., March, 1913.

Mr. Clarke.

The first requisite pertaining to the location of a levee in this region is a careful underground survey to determine the sort of material to be encountered in excavation for muck-ditches. Large deposits of unfit material, such as adobe, heavily alkaline soil, and certain kinds of sand, must be avoided by detours. Seepage is the only factor detrimental to the land-side borrow-pit plan, and that is to be eliminated by the muck-ditch. The theoretical additional head against the levee, due to a borrow-pit 40 ft. in the rear of the levee, is a negligible factor. Under conditions actually encountered on the Colorado, there is not any additional head, either in fact or in theory. That objection to the land-side borrow-pit is not even theoretically plausible.

Essential Features.—The essential features of efficient levee construction on the Lower Colorado are: location avoiding bad ground and careful muck-ditching to exclude seepage; land-side borrow-pits, leaving all natural protection on the river side undisturbed; gravel blanket to resist erosion and to minimize attacks by burrowing animals; railroad tracks on top of the levee to facilitate maintenance and to make possible the protection of banks and levees by permanent rock revetment.

Mr. Sellew is unquestionably right in his conclusions:

"That in their present state, the levees are at the mercy of the meanders of the stream, except throughout those portions where a railroad occupies the levee top"; and, "That bank revetment, permanent in character and reasonable in cost, when compared with other methods, can be readily and quickly accomplished with rock placed from railroad trains operated on the levee tops and connecting with existing quarries which are within a reasonable distance."

The first conclusion is sustained by the history of all the Colorado levees, and the correctness of the second was demonstrated clearly in 1907 by the holding of the 1 400-ft. section of levee against the attack by a flood of 40 000 sec-ft. at the time of the last closure. The permanency of rock revetment thus constructed, however, depends on the placing of gravel as a bed for the rock. That is a vital detail of the method.

In rip-rapping levees and reveting the banks at the toes, in the opinion of the writer, grading to uniform slope is not only unnecessary, but inadvisable. It is better to place the gravel and rock on the natural ground. Setting rip-rap by hand on the face of a levee makes a neat looking job, but it is needlessly expensive, and the protection is less effective than that secured by the gravel and rock method.

Before leaving, finally, the subject of closure of the crevasses and the preservation of Imperial Valley in 1906-07, the writer desires to put on record the fact that the accomplishment of the work was due primarily and exclusively to the independent judgment and courage

of Mr. Harriman, who persisted in his belief that the breaks could be closed, and his determination to close them in the face of opposition, and regardless of the positive assertions of a host of eminent engineers that closure was a physical impossibility. Mr. Clarke.

Submerged Weir.—Mr. Cory has described briefly the submerged rock weir placed across the river at the intake of the Imperial Valley Canal in the summer of 1910, and has mentioned its unexpected stability and durability. Mr. Sellew does not discuss the weir or its effects directly, possibly because he did not view its construction with favor, but his comment on Mr. Cory's statement concerning the permanency and efficacy of rock fill in the crevasses has bearing on the subject. Of the rock fill Mr. Sellew says:

"How it would act as an overflow weir, carrying 150 000 sec-ft., even if covered with concrete, is problematical. In addition to a concrete top, crest and foot-walls appear to be necessary to prevent the top from being undermined, and, if these are provided, the resulting structure will not differ materially from Laguna Dam either in design or cost."

This is a case in which accomplished facts fail to justify speculative theory, and it appears to be in order for the writer, as the builder of the weir, to state the facts and show the actual effects of the installation.

Construction of the weir was necessary because of the recession of the bed of the river, following the diversion of all its flow into the Abejas channel, and because of the lack of a powerful dredge to keep the floor of the 1 900-ft. intake from the river to Hanlon gate as low as the sill of the gate. The discharge of the river was diminishing, and danger of complete diversion of the channel from the intake was imminent. The placing of a weir to check recession and direct the current was the only practicable rapid method of returning the water to the canal and saving a $6 000 000 crop in Imperial Valley.

A trestle, 960 ft. long, composed of four-pile bents, 15 ft. between centers, was built across the river, below the intake, to the Arizona shore, at an angle of approximately 70°, the Arizona end being the farther up stream. Caps, stringers, ties, and rails were placed on the structure, and steam-shovel rock from the adjoining quarry was dumped from the trestle and spread to a width of 50 ft. No brush at all was used, and no derrick rock was dumped. As the weir was designed to be temporary, no gravel was placed either before or with the rock. The discharge of the river during the progress of the work was about 9 000 sec-ft.

The weir was constructed in 21 days, at a cost of $22 500, of which amount $4 000 was recovered in salvage of rails, ties, stringers, and caps. The quantity of rock used was 12 800 cu. yd., of which 9 600 cu. yd. were placed in the weir, the rest being used to revet the banks

Mr. Clarke.

and raise a spur track above the high-water mark of 1909. The angle of the weir to the current served to point the channel to the California shore, and also served other purposes familiar to "firing-line" railroad engineers.

The weir arrested the recession of the river bed, turned the water into the intake, averted a water shortage in the Imperial irrigation system, and saved to the farmers of Imperial Valley crops worth \$6 000 000 or \$7 000 000. Also, the successful construction and operation of the weir demonstrated that the farms of Yuma Valley, dried out and virtually abandoned for 5 or 6 years, could have been watered at small expense, and could have produced and marketed crops to the value of \$1 000 000 a year while awaiting the completion of those great engineering monuments, the Laguna Dam and the Colorado River Siphon. It is evident that the lands of Yuma, Cibola, and Parker Valleys can be provided with water by the construction of weirs, and brought under cultivation at nominal expense.

Although the piling of the trestle was cut off above the rock fill and removed in the spring of 1911, the rock weir remained in place. How such a fill would stand an overpour of 150 000 sec-ft., even without a concrete top, is not problematical in any sense. The weir at the intake has endured two freshets, one of 150 000 sec-ft. and the largest on record, and it still remains. It has neither crest, core, nor footwall of concrete, and it is not covered with concrete, but its top has not been undermined. It differs radically and widely from Laguna Dam in design and cost, but its function is the same. A permanent rock-fill weir, built with gravel, large rock, and steam-shovel rock, and having a cross-section width of 200 ft. on the bottom, certainly would stand any overpour that the Colorado could muster, and its cost would be comparatively small.

Useless Dredging.—Although the work of a dredge in the intake above the concrete gate was of material aid in getting an adequate supply of water to the canal, the writer cannot concur in the opinion that the operation of the dredge *Imperial* below the gate was of the slightest efficacy or value at any time. The dredge has dug a hole below the gate; the hole has been filled with sand; the dredge has dug it again, and so on in one continuous round of costly futility, like the labor of Sisyphus. Had the *Imperial* been placed above the gate, it would have been useful. When the banks of the Alamo channel, constituting the main canal, had been raised and strengthened to carry safely a large flow, the discharge of from 2 500 to 3 000 sec-ft. through the gate solved the problem of water supply for the valley canal system. In an hour and a half 2 500 ft. of water sluiced sand from the canal below the gate to the depth of 1 ft. The Alamo Canal is an efficient channel for 5 miles below the gate, when carrying 2 000 sec-ft. or more, and dredging is wholly useless.

When the writer took charge of work on the C. D. Co. system, he found two large dredges, the *Delta* and *Gamma*, at work in the main canal at an operating cost of $9 000 a month. The dredges were useful in straightening the course of the Alamo, cutting across bends and building up banks, but when they operated in the canal to remove silt and sand, they only moved a hole up and down stream. Careful instrumental observations and cross-section surveys showed that the floor of the canal behind a dredge was at the same level as before the dredge reached it. Mr. Clarke.

The writer put the dredges out of commission and tied them up, thereby saving $9 000 a month. It is doubtful if a dredging barge, occupying more than one-third of the width of a canal carrying Colorado River water (laden heavily with silt and sand), can be operated efficiently to remove deposits.

The removal of quicksand from the Imperial canals is a problem to be solved by the managers of the main supply system. Sand in the canals of the Mutual Companies constitutes a menace, and is a cause of great increase in maintenance expense. The deposit of sand in these canals and in farmers' laterals is avoidable. Doubtless a small percentage of sand brought through the head-gate is removed by the *Imperial*, but all of it could be removed more economically by other means at the lower end of the Alamo main, and it is obviously the business of the C. D. Co.'s Receiver to take care of that sand instead of sluicing it out upon the valley farms.

Summary.—The writer has endeavored to make clear, by statement of fact and description of work accomplished, that there is no abstruse problem involved in placing the Lower Colorado under control and confining its floods to a determined course.

The meanders of the river are subject to direction by simple and inexpensive means, the current at the early stage of its wandering tendency responding as readily to the guiding hand as does a bridlewise horse to the touch of rein upon the neck.

The permanent revetment of the banks has been demonstrated to be comparatively easy of accomplishment by methods familiar to, and applied by, railroad engineers in the West for many years.

That a railroad on the top of a levee is indispensable to maintenance and to application of the rock-fill method of bank revetment has been shown conclusively by experience. Costly experience has proved the unwisdom of removing any natural protection from the berm on the river-side of a levee, and has established the correctness of the railroad "firing-line" practice in the construction of embankments along streams, particularly those flowing through regions of alluvial formation.

Submerged weirs, to raise the bed of the river, arrest the recession of scour planes, and divert water with certainty and safety into canal

Mr. Clarke. intakes, may be built as permanent structures by the simple and inexpensive method of dumping gravel and rock from trestles, without placing any crest or core-walls, or using a pound of cement.

The operation of dredges for the removal of sand from main irrigation canals is ineffective and a waste of money where water can be carried in large volume at sluicing velocities.

Mr. Marshall. U. S. MARSHALL, ASSOC. M. AM. SOC. C. E. (by letter).—The author's statements regarding the very unfavorable soil report on the Imperial Valley, issued by the U. S. Department of Agriculture (which actual results have proven to be unjustified), and the belief expressed that, had this soil report been issued before the reclamation of the valley was well under way, the effect would have been a complete condemnation of the project, are serious matters and worthy of most attentive consideration. The writer has had similar experience, and has no doubt that many others interested in reclamation work have encountered this same bugaboo of an adverse Government soil report. It is certainly the duty of the U. S. Bureau of Soils to rectify some of the wrongs done to different parts of the country through adverse reports on various soil types. The writer knows of no case where this has been done in a way which has had any practical effect.

The object of a soil survey should be to determine what the land is adapted to and what methods of cultivation are indicated and required. The findings of a survey should be, by all means, of a constructive and not of a destructive nature, and the chief purpose should be to find some beneficent use for the soil surveyed. Any report that condemns a soil type as worthless, unless based on the most thorough investigation, necessarily does a most serious and inestimable injury to the area reported on.

It should be the office of the Government to encourage the development of waste land, but certainly some of the soil reports would discourage even a preliminary investigation of the areas in question. Because of the usual high respect for Government experts and their disinterested attitude in such matters, their statements, official and otherwise, are generally taken as expressions of ultimate facts, and unimpeachable as to the conditions of the soils reported on. However, in the West, to-day, there are notable cases of great districts, with proven agricultural value, which were condemned by the Government Bureau of Soils.

The writer's experience with an adverse soil report will serve as another example, supporting these statements. While one of the engineers was making a report on a proposed 60 000-acre levee reclamation project in the Sacramento Valley, California, on which it was estimated $2 000 000 would be spent for levees and drainage works, the following developed:

The project had advanced to the point where the parties who were to finance it had paid for 26 000 acres of the land involved, and plans were being hurried for the reclamation works, when the U. S. Department of Agriculture's "Soil Survey for the Marysville Area, California," was called to the attention of one of the several representatives of the purchaser. This report, issued in 1911, was the work of Messrs. A. T. Strahorn, W. W. Mackie, H. L. Westover, L. C. Holmes, and Cornelius Van Duyne, and on page 30 contained the following comment regarding that part of the area in which this project was located: Mr. Marshall.

"When protected from overflow by levees, this soil will be saturated for some portion of each year on account of the high water level outside the levees. Extensive drainage ditches and pumping plants would remedy this to a considerable extent, but to keep down the level of the water table for such extensive areas would be very expensive, and only the most profitable crops would justify the expense. The physical condition of the soil is about as unfavorable as it possibly could be, owing to water-logged condition and consequent nonaeration. Should the type ever be thoroughly protected from inundation, the agricultural value of the section will probably depend upon the introduction of crops suitable only to low, moist land that will yield a considerable return for the labor and money invested.

"The following table gives the results of a mechanical analysis of a sample of the soil of this type [amounts given in percentage by weight]:

Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
0.0	0.5	0.7	3.4	1.8	41.0	52.7"

This report, coming from the Government, and obviously unbiased, seemed to this representative to be a solar plexus blow to the project, and he felt that the purchaser had been misled. The parties effecting the sale felt that their reputation was in jeopardy. They had never seen the soil report, but were positive, because of actual results, that the soil was very productive. The engineers were censured for failing to bring the report to the attention of the parties interested, and it seemed certain that the whole project would fall through.

In an effort to re-establish confidence, a large number of representative farmers, experienced in handling bottom lands, were taken over the area and asked to pass judgment on the soil. All agreed that any land supporting a heavy tule growth was valuable when reclaimed, as much of this identical soil which had been reclaimed in the Sacramento Valley produces great crops. Much of the land in this area, however, is not covered with tules, and these bottom-land farmers would not vouch for it because they could see no native tule growth, which was the basis for their conclusions. In this diffi-

Mr. Marshall.

culty the writer had recourse to the United States Government surveys made in 1854 and 1864. In these notes frequent reference was made to tule growth encountered. On platting these, a map was obtained showing that the tule growth in 1864 covered nearly the whole of the area in question. This was accepted as convincing proof of the continuity of soil type, and the purchaser was reassured to the extent that reclamation is now going on.

There will thus be created for the community a vast acreage of exceptionally productive ground which, had it been impossible to offset the adverse report of the soil experts, would have continued a worthless expanse of duck marsh, and the reputation of many men of high standing would have been shattered and confidence in their integrity and judgment lost. Further to re-establish the reputation of the land and prove the mistaken character of the soil report in question, comparisons were made with the "Soil Survey of The Woodland Area, California," by the U. S. Department of Agriculture. This area adjoins that of Marysville, and was reported on by Messrs. C. W. Mann, J. F. Warner, H. L. Westover, and James E. Ferguson. The soil type commented on so adversely in the Marysville Area is reported on as follows in the survey of the Woodland Area, page 25:

"Where this soil type is protected from overflow and is free from alkali it is adapted to grain, sorghum, Egyptian corn, hay, and other forage crops.

"The texture of the soil * * * is shown in the following table [by percentages]:

Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
0.1	0.7	0.9	3.3	1.4	41.2	52.3"

The survey of the Woodland Area was made prior to that of the Marysville Area. The mechanical analyses of the two soil types are identical. In reporting on the Woodland Area there could have been no mistake in advising on its adaptability for the crops mentioned, for, at the time the survey was made, the land was producing a very heavy alfalfa crop.

It should be remembered that all information, used in showing the original Marysville Area report of this soil type to be grossly in error, was as available to the Government soil experts as to the writer, and that for their most adverse report on the soil in question there is no real excuse. Nevertheless, as it was obvious that an error had been made, a supplementary report revising the survey of certain soils in the Marysville Area has been issued by the Government, in which the former report was corrected and the mistakes excused on the ground that at the time the survey was made the soil in question was covered

with water, thereby making thorough investigation difficult! Certainly this was reason enough for failure to get good first-hand data; but why should a report be made condemning many thousands of acres of land on such flimsy investigation? Mr. Marshall.

The writer dissents from Mr. Sellew's comments as to the propriety of including the discharge records at Yuma prior to 1903, in Table 3. All available data should always be given, with explanations, and thus permit the reader to draw his own conclusions according to his own experience and judgment. Furthermore, the result of taking the yearly rainfall for the entire 265 000 sq. miles of water-shed of the Colorado River as the combination of yearly rainfalls at eight different stations scattered over the water-sheds, which it was assumed gave a fair average, does not seem to be justifiable. This is shown by platting the average rainfalls and yearly run-offs, as given by Mr. Sellew for 1903 to 1912, as in Fig. 45. This proves that there is no law that can be deduced connecting yearly rainfall and run-off totals on a water-shed as large as that of the Colorado River, and that one cannot tell with any more certainty than a guess what the run-off of the Colorado River was by using the rainfall data of the eight rain-gauge stations selected.

COMPARATIVE PRECIPITATION AND RUN-OFF
COLORADO RIVER VALLEY
1903–1912.

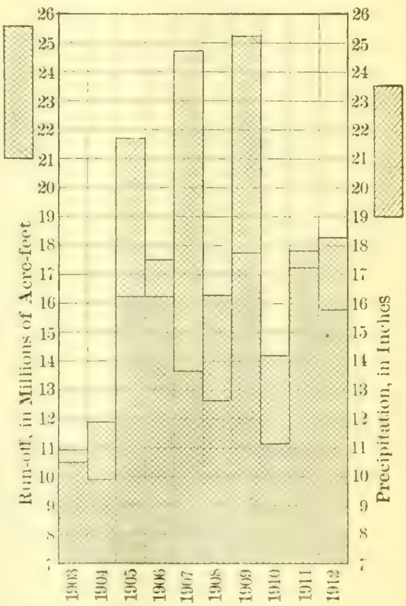

FIG. 45.

Therefore, to condemn the discharge records at Yuma prior to the establishment of permanent gauging stations there, as being too low, because they do not conform closely to what one might expect from the rainfall records given, in the writer's opinion, is wrong. The early data are not precise, but they are valuable and should have weight in the consideration of the problem.

That there may be long cycles of high and low yearly discharge of rivers is well established. The writer calls to mind some investigations which he made into the past levels of the Great Salt Lake. By inquiry from old settlers and by searching records it was found that in the last century Great Salt Lake had two cycles, and probably three, of extreme high and extreme low water, and, according to such

Mr. Marshall.

experience, the lake should be high at this time, and such is the case. The lake is now some 8 ft. higher than it was at the time of the construction of the Lucin Cut-off in 1902, and this rise has taken place in spite of the fact that, for irrigation purposes, much more water than formerly is now being diverted from the rivers emptying into the lake.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

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FREMANTLE GRAVING DOCK: STEEL DAM CONSTRUCTION FOR NORTH WALL.

Discussion.*

By Herbert E. Bellamy, Assoc. M. Am. Soc. C. E.

Herbert E. Bellamy, Assoc. M. Am. Soc. C. E. (by letter).—The writer has read Mr. Ramsbotham's paper with much interest, and is glad that a matter of such importance has been presented before the Society. Mr. Bellamy.

As the writer has had considerable experience with jarrah timber for walings and shores, as referred to by the author, the following remarks may not be considered out of place.

Jarrah (*Eucalyptus marginata*) is one of the most valuable of Western Australian timbers, and one of the best in the Australian Colonies. It is, perhaps, more widely known to engineers outside Australia than any other timber grown there. It is exceedingly durable, whether exposed so as to be alternately wet and dry, or used as piles in sea-water or damp ground. Its weight varies from 56 to 68 lb. per cu. ft. Recent tests of this timber afford the following information:

Transverse strength per square inch..........	1 800 lb.
Tension: direct cohesion on 1 sq. in..........	2 940 "
Crushing strain on 2-in. cubes..............	3.198 tons

It is a singular fact, however, that the majority of engineers throughout Australia do not view with favor the use of hard woods for walings.

One particular instance, in which absolutely nothing but jarrah was used for timbering, was in the excavation for the main pumping station executed under the writer's supervision in connection with the Colombo (Ceylon) Main Drainage Works, for which works, Messrs. James Mansergh and Sons were the Consulting Engineers. All the

* Continued from April, 1913, *Proceedings*.

Mr. Bellamy. walings and struts were 12 by 12-in. and fixed at 4-ft. centers. Fig. 6 illustrates the system adopted. All sets were independent and in 20-ft. lengths, so as to facilitate the easy striking of the timbers as the masonry arose from the bottom.

When the excavation was down to formation level and all timbers were in, heavy monsoonal rains set in, and the trench was allowed to be flooded for several weeks. After the rains had ceased, pulsometer pumps were fixed, and the water was pumped out so that the bottom concrete could be put in. On several subsequent occasions, the trench was flooded and pumped out again. This alternate wetting and drying would naturally tax any timber, but the writer can state with every confidence that every waling and strut removed from this excavation after being in use for about 12 months, was in practically the same good condition as when first put in. Indeed, the majority of the timbers taken out were sawn into 12 by 6-in. and 12 by 3-in. scantlings and used in other parts of the work.

The writer has also used jarrah extensively for side-trees, head-trees, and sills in tunnels, which have been flooded on several occasions, and not in a single instance was there failure or disappointment.

Steel sheet-piling has been used so extensively and successfully, and in so many different classes of work, that the author's elaborate description calls for no further comment.

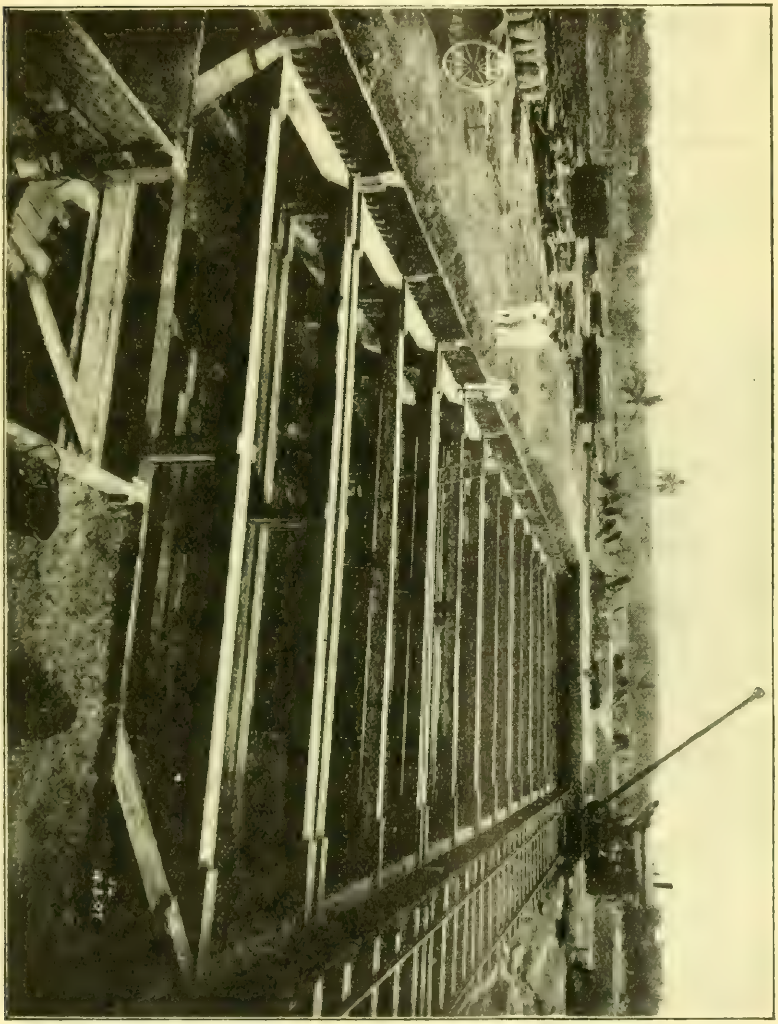

FIG. 6.—WIDE TRENCH, AT COLOMBO, CEYLON, SUPPORTED BY 12 BY 12-IN. WALING AND STRUTS OF JARRAH TIMBER.

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TIDAL PHENOMENA IN THE HARBOR OF NEW YORK.

Discussion.*

By Messrs. Allen Hazen, T. Kennard Thomson, James Owen, and Kenneth Allen.

Allen Hazen, M. Am. Soc. C. E.—It is extremely fortunate that the observations recorded in this paper have been made, and that they have been compiled and put in convenient and readily understood shape. The author's method of analysis follows closely that used by the speaker in discussing the same problem† seven years ago. At that time the data for salinity, tidal flow, and fresh-water flow, were meager, and there was no information as to the extent of underrun. The figures then obtained, with limited data, in comparison with those of the author, are given in Table 31. The author's figures Mr. Hazen.

TABLE 31.

	Annual Average Figures:	
	Hazen, 1906.	Parsons, 1913.
Ebb Tide:		
Percentage of river-water on its last trip out	7	9.8
Percentage of river-water which will come back	28	25.0
Percentage of sea-water on its last trip out	14	18.4
Percentage of sea-water which will come back	51	46.8
Flood Tide:		
Percentage of new sea-water which has never been in the harbor before	23	20.5

* This discussion (of the paper by H. de B. Parsons, M. Am. Soc. C. E., published in April, 1913, *Proceedings*, and presented at the meeting of May 7th, 1913), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† *Journal*, Assoc. of Eng. Societies, Vol. XXXVI, p. 293.

Mr. Hazen. afford a striking confirmation of the substantial accuracy of those used by the speaker in discussing the sewage disposal problem in the harbor at that time, and in a professional report made soon afterward.

The figures in Tables 18 and 19, containing corresponding data by months, are most interesting. The quantity of new water passing The Narrows at each tide by months from these tables, and the corresponding flow of a stream necessary to furnish an equal quantity of new water in the course of the 24 hours, are as shown in Table 32.

TABLE 32.—New Water in the Harbor with Each Tide, in Millions of Cubic Feet, During Ebb Tide.

Month.	Land-water.	Sea-water.	Total.	Totals, in cubic feet per second.
January	880	2 240	3 120	70 000
February	690	670	1 360	30 000
March	2 500	2 510	5 010	112 000
April	2 590	1 740	4 330	97 000
May	1 340	1 050	2 390	54 000
June	1 090	1 780	2 870	64 000
July	700	2 180	2 880	65 000
August	620	1 520	2 140	48 000
September	710	2 150	2 860	64 000
October	990	3 610	4 600	103 000
November	910	3 190	4 100	92 000
December	1 070	3 470	4 540	102 000
Averages	1 180	2 210	3 390	76 000

The figures in Table 32 show that 65% of the new water in the harbor throughout the year is sea-water, and that 35% is land-water. For every cubic foot of water that goes through The Narrows from all the rivers draining 14 395 sq. miles, 2 cu. ft. of water come in from the ocean, circulate up and down the harbor, and go out to sea again. The exchange of water in the harbor is as great as that which would result from the fresh water from an area of 41 000 sq. miles. Practically, it is equivalent to much more, because, in a river, the flow is variable, and there is a period in summer when it is much less than the average. In New York Harbor there is, practically speaking, no dry-weather period. When the flow of fresh water is less, the flow of sea-water is greater, and the total flow is maintained so that the minimum is a larger percentage of the average than would be the case in any natural river.

The author's figures indicate a minimum flow for February of 30 000 cu. ft. per sec., between much larger values for January and March. The low figure for February is due to a very low figure for sea-water exchanged during that month. The reasons for fluctuations in the volume of land-water are obvious, but there is no apparent reason why the quantity of sea-water should fluctuate to as great an

extent as is indicated by Table 32. The tide must have risen and fallen during that month as in other months, and the opportunities for exchange of sea-water were the same as at other times. When the rivers are in flood, the quantity of fresh water entering the harbor is greatly increased, and tends to take the place of, and keep out, an equal volume of salt water. For the February in question no such condition existed. On the other hand, the land-water was nearly down to the low figure for the year. The speaker thinks that the explanation of this apparently low February flow is to be found in some matters, not sufficiently taken into account in the calculation, which, perhaps, cannot be taken into account at the present time. Mr. Hazen.

The assumption is made, if the speaker understands correctly, that the quantity of water passing through The Narrows during each month is the same as that of the fresh water flowing in all the tributary rivers. This assumption must be more or less in error, because, obviously, there is retardation of the flow of fresh water through the large and variable reservoir of brackish water between The Narrows and the farthest points to which salt water extends. This retardation must have the effect of modifying, probably to a substantial extent, the quantity of fresh water flowing through The Narrows during any calendar month. If these differences could be adequately taken into account and allowed for, the speaker suggests that the monthly variation of the combined flow might be found to be more nearly constant than is indicated by the author's tables. Taking this matter into account probably would not greatly change the annual average figure. It would have a steadying effect on the monthly flows, and reduce the fluctuations.

If it is assumed that the lowest months in the author's tables may be accounted for in this way, it appears that the exchange of water in the harbor is equivalent to a steady flow of between 50 000 and 100 000 cu. ft. per sec., averaging 76 000 cu. ft. per sec. In comparison with this, the speaker, in 1906, on the basis of the few data then available, estimated the corresponding flow at 68 000 cu. ft. per sec. No river in the United States has a minimum flow as great as this. Probably no other great city in the world is as favorably situated as New York on rivers having currents of such volume and strength.

It has been sometimes assumed that a flow of 3 cu. ft. per sec. would suffice to dilute the sewage from 1 000 people enough to make it inoffensive. This ratio is not everywhere accepted, but, taking it as a basis, if the flow through The Narrows could be fully utilized for dilution, it would serve to carry off the sewage of from 17 000 000 to 34 000 000 people. Even if a larger relative dilution is assumed to be necessary, as, for instance, 4, or even 5 cu. ft. per sec., per 1 000 of population, it is still adequate to serve a population which will not be attained for many years.

Mr. Hazen. One of the practical difficulties, in the utilization of this great water quantity for dilution, is to arrange matters so that the sewage will be mixed evenly with it. At present more than a proportionate quantity of sewage is discharged into some branches of the harbor, as, for instance, into the East River and the Harlem River, and these branches have a higher relative pollution and are nearer to a permissible limit than is the harbor as a whole.

The figures for tidal flow, put in convenient and accessible form in this paper, will be of the greatest service in future discussions of this most important question.

Mr. Thomson. T. Kennard Thomson, M. Am. Soc. C. E.—The Society owes a hearty vote of thanks to Mr. Parsons for this very valuable and interesting paper. It is especially interesting to the speaker on account of his plan for relieving the congestion in New York Harbor.

This plan has already been brought to the attention of the Society,* and this opportunity is taken to show the same plan with an addition, Fig. 63, which has been seriously suggested by a very able man.

The plan consists of the reclamation of the East River, and the building of a serviceable channel between Flushing and Jamaica Bays. This would reclaim about 10 sq. miles between Manhattan and Brooklyn, and also solve many of the rapid transit problems, as well as the dock problems.

Mr. Parsons' paper proves that the speaker's original proposition would have a very insignificant effect on the waters passing through The Narrows, stated to be 75 000 cu. ft. per sec., as referred to by Mr. Hazen. The Mohawk River, alone, during the floods of March, 1913, discharged 96 000 cu. ft. per sec. into the Hudson River, though its discharge in summer is often less than 2 000 cu. ft. per sec. This, of course, is unusual, but the ordinary variation in the quantity of water entering the Hudson River from its tributaries makes the displacement, suggested by the speaker's plans, insignificant.

The carrying out of this plan would insure the greatest boom that has ever been thought of for New York City and State, and the population of the city would increase to 12 000 000 and more in a very short time.

Mr. Owen. James Owen, M. Am. Soc. C. E.—The speaker has been interested in the tidal flow in New York Harbor for some years, and there seems to be an element in the whole question which has not been considered by any one except Mr. Thomson, who is rather ahead of the proposition, that is, the gradual closing of the harbor itself.

Some years ago the speaker had occasion to take some evidence and make some tests on the encroachment on the shores on the New

* "The Problem of the Lower West Side Manhattan Water-Front of the Port of New York," by B. F. Cresson, Jr., M. Am. Soc. C. E., *Transactions*, Am. Soc. C. E., Vol. LXXV, p. 268.

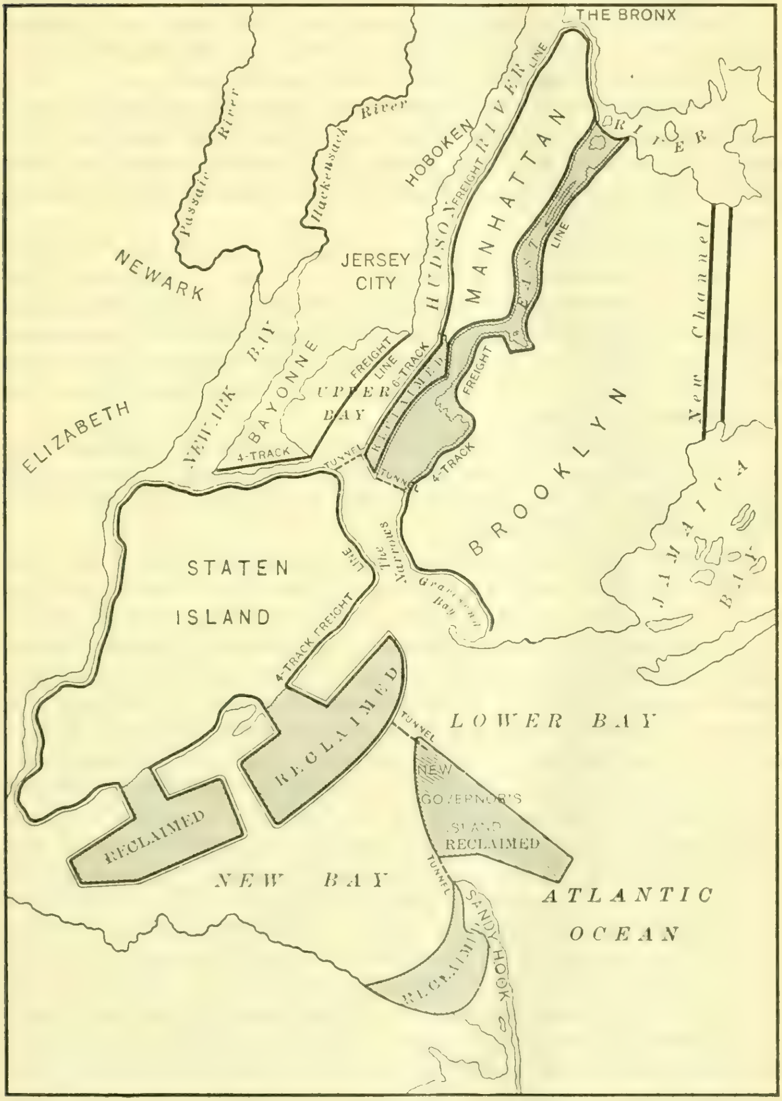
THE BRONX
Passaic River
Hackensack River
HOBOKEN
HUDSON RIVER
FREIGHT LINE
MANHATTAN
EAST RIVER
LINE
NEWARK
JERSEY CITY
New Channel
NEWARK BAY
BAYONNE
FREIGHT LINE
UPPER BAY
6-TRACK
RECLAIMED
FREIGHT
BROOKLYN
ELIZABETH
4-TRACK
TUNNEL
4-TRACK
JAMAICA BAY
The Narrows
STATEN ISLAND
LINE
Gravesend Bay
4-TRACK FREIGHT
RECLAIMED
LOWER BAY
TUNNEL
RECLAIMED
RECLAIMED
NEW BAY
TUNNEL
ATLANTIC OCEAN
SANDY HOOK

FIG. 63.

Mr. Owen. Jersey Coast, and incidentally he examined into the question of the opening of New York Harbor. It was found that two elements entered into that question, namely the deposit by fresh water from the high grounds above, and the gradual throwing up of the sands by the storms on the coast. It was found that the accretion at the estuaries of the New Jersey Coast amounted to about 3 ft. in 30 years.

At some prehistoric period, the Jersey Meadows were covered with water, and they have all been filled up. It was found that there were some 21 estuaries on the Jersey Coast which have been closed up in the last 150 years, and that Sandy Hook was at one time merely a cluster of islands.

The report of the Jamaica Bay Commission showed that the Rockaway Spit had encroached to the east about 1 mile in 30 years. Considering this encroachment and that of the Sandy Hook Spit, which is about in the same ratio, one may note the probability of the gradual closing up of New York Harbor, not only by the deposits of the waters themselves—which are very small from the Hudson River—but by the encroachment of the sea.

Whatever experiments are made will have to be carried along year by year, counting on the encroachments of the ocean. It is a very important question, this gradual closing up of New York Harbor by the encroachment of the sea.

Mr. Allen. KENNETH ALLEN, M. AM. SOC. C. E. (by letter).—The author has described the tidal condition existing in New York Harbor so fully that little remains to be added. The special application of tidal studies to those of sewage disposal is obvious. Dilution of a sewage effluent may be secured by the variable currents induced by winds and differences of temperature, as in cities discharging sewage into a lake; but, in general, dependence is placed on the much more reliable and effective currents due to the flow of upland waters in rivers or the tides of the sea. In the case of New York City, though large dependence is placed on the upland waters discharged by the Hudson River, the condition of the East River and Upper Bay depends in a great degree on the refreshing influence of the new sea water brought in twice a day by the tides. To a much greater extent is this true of the two shallow bays—Newark and Jamaica—the waters of which receive large volumes of sewage, but yet contain a fair amount of dissolved oxygen brought in by the proportionately large tidal prism at every tide. Owing to the existence of such connecting waterways as the East and Harlem Rivers, Little Hell Gate, Bronx and Arthur Kills, and Kill van Kull, combined with the varying conditions of flow in the Hudson River, the tidal phenomena of New York Harbor are as complex as could well be imagined, and a reasonable approach to true average conditions can only be found by a long series of observations. In the case under discussion, much information was available from past observations of

the U. S. Coast Survey and the War Department, but, especially with reference to the East and Harlem Rivers, this was incomplete and has but recently been secured by Col. W. M. Black, Corps of Engineers, U. S. A. Mr. Allen.

Aside from velocities and discharges at certain points or cross-sections, information was desired by the Metropolitan Sewerage Commission as to the probable dispersion and drift of floating solids if set adrift at specific points, and though the float observations which were undertaken provided a certain amount of general information regarding probable velocities, on which discharges might be estimated, dependence could not be placed on these alone for the latter purpose, owing to the manifest discrepancies due to local or temporary conditions.

Float observations, however, are valuable as an indication of the probable trend of sewage (which in salt water rises to near the surface), its oscillation back and forth with the tides, and of the shores on which its floating constituents may strand.

In 1897 the writer made a series of float observations for the Baltimore Sewerage Commission* in Chesapeake Bay off North Point, to determine the most favorable location for the discharge of sewage. At six selected points, about ½ mile apart and from ⅝ to 2½ miles from shore, poles were set in the bottom, which was nowhere more than about 20 ft. from the surface at low water, the tidal range being about 1 ft.

A 30-ton schooner was chartered and anchored in the vicinity of the work as headquarters for the party, which consisted of an observer, a recorder, the captain, mate, and cook. A small steam launch, with captain and engineer, was secured with which to follow the floats. For communication with the party a tug was engaged.

The floats consisted of 2 by 2-in. by 7-ft. yellow pine sticks weighted on the lower end by cast-iron washers strung on a wire until only 5 or 6 in. of the other end were left above water. A ¼-in. iron rod was inserted in this upper end on which a 12 by 12-in. red or black flag was attached bearing a serial number in white. These were set adrift at the several points in succession, beginning at about 6 A. M. and continuing at stated intervals, by a man in a rowboat. They were observed by sextant as often as practicable from the launch, passing from one float to another until dark. No attempt was made to recover the floats, which finally went down the bay or grounded on shoals.

In this way 150 floats were set adrift during an entire month, May 27th to June 26th, so as to include all phases of the moon and tide.

* Report, Baltimore Sewerage Commission, 1897, Mendes Cohen, Past-President, Am. Soc. C. E., Chairman.

Mr. Allen.

A tide gauge was set up at a neighboring light-house and a record of the tides and wind was kept during the work.

The cost of these observations was:

Schooner, crew, and launch	$296.98
Salaries	378.50
Provisions	53.91
Coal for launch	32.00
Floats	70.05
Supplies, fares, and miscellaneous	53.44
Plotting traces of floats on charts	54.50
Total	$939.38

On account of the unseaworthiness of the launch in bad weather 10½ days were lost.

By this method, a large number of observations were made during the day of floats set out at different points, at different times, and at different stages of the tide. The records of individual floats were not very complete, nor were they often continued beyond the day they were set adrift, but, taken together, they indicated very graphically the points likely to be reached by floating matter starting from any one of the six assumed points of outfall.

They also indicated: (1) a general trend off shore toward the main ship channels and away from the oyster beds which were farther down the bay and near the shores, or in the estuaries; (2) that under rare conditions would floating material set out at the point finally recommended (2 miles from shore) be carried up the Patapsco River as far as Sparrows Point; and (3) that after a continuous discharge for 33 consecutive hours sewage would be dispersed in all probability over an area of some 16 sq. miles, and hence become thoroughly diluted.

The type of float selected was inexpensive and, on the whole, satisfactory, being convenient to handle and but little affected by the wind. Tests were made with black, white, and red flags, and, contrary to expectations, the black was generally discovered most easily and white the least so, although this depended on the weather. Red or black flags, appearing the same in the distance, were usually first seen with low-power field glasses at distances ranging from ½ to 1 mile.

The New York experiments, taken up by the writer in 1908, were conducted under quite different conditions.* Considerable populations occupy the shores for many miles along the several watercourses, and the currents are so swift as to render useless any attempt to follow any number of floats with one boat. It was decided, therefore, to set out only one float at a time and observe its position at frequent in-

* Report, Metropolitan Sewerage Commission of New York, 1910, George A. Soper, M. Am. Soc. C. E., President.

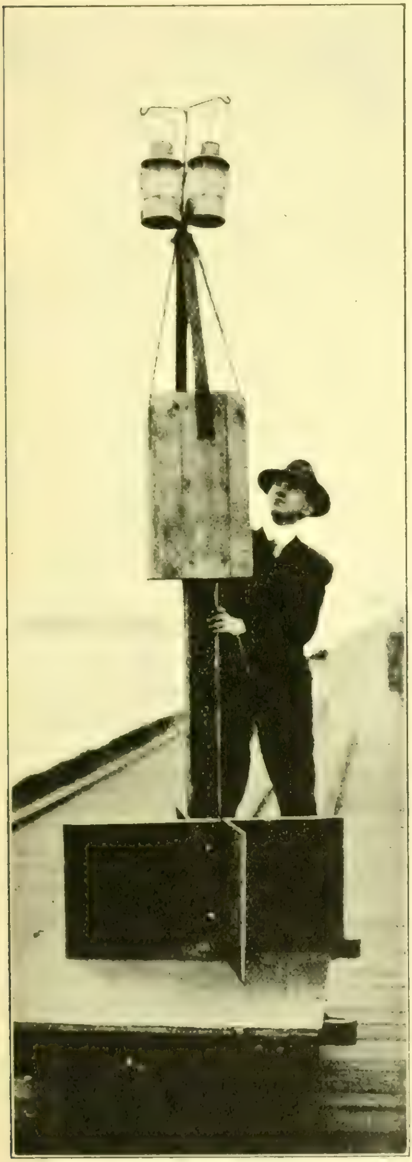

FIG. 64.—SPAR FLOAT.

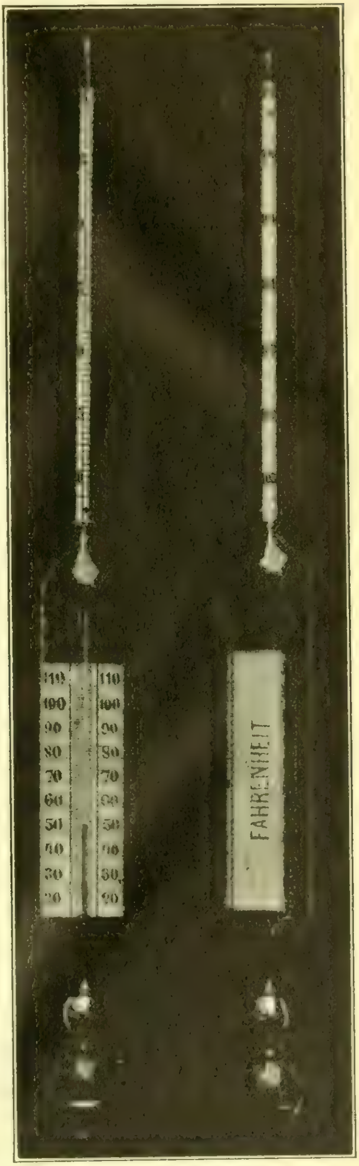

FIG. 65.—SALINOMETER.

tervals throughout the day. To avoid the loss of the float by the absorption of water, the double-can type, described by the author, was devised. This was found convenient, inexpensive, and in general satisfactory, except that it was easily destroyed by being run down by tugs in the crowded waterways. Also the small flag which it was intended should be carried by the upper can made it top-heavy, and, as the observer was never far from the float, the flag was finally omitted as unnecessary. Mr. Allen.

During the following year the longer "spar" float, Fig. 64, was adopted and found well suited to the conditions to be met. It was open to the objection found with the Baltimore float of absorbing water, but, having large submerged vanes, the influence of the wind was relatively small, and there was no objection in allowing the top to project above the water sufficiently to prevent loss from this cause. The size of this float, moreover, permitted two lanterns to be carried on a $\frac{3}{8}$-in. steel rod supported by a light frame at a height of some 3 ft. or more above the water surface, and so it was possible to follow the float by night as well as by day. This was found essential in order to secure the information desired.

Locations in the open water of the bay were generally made with a sextant, as on the Chesapeake Bay work; but, in the strong currents of the rivers, and when near the shore, where locations could be identified, an estimate of the position noted briefly in the recorder's book was found more reliable. The azimuth compass was used to a limited extent in taking bearings up or down stream to objects not too distant, such as bridge piers, but was found unreliable where the plotted position depended on the accuracy of the bearing from a distant point, and considerable care was required to see that the dial swung free.

Although these experiments were intended primarily to indicate the possible drift of floating matter, the results have been utilized in confirming or modifying existing values for the velocity at strength of tide, and for the tidal flow at different points in the harbor.

Where current velocities at specific locations were desired, these were obtained by anchoring at such locations and noting the time taken by a double-can float to drift 100 ft. The distance was measured by a fine cord attached to the float, and the time by a stop-watch.

In order to obtain continuous night-and-day observations, three motor boats were chartered, each with an observer who was to follow the float for an 8-hour shift, but the long distances traveled during a tide, the inaccessible location of much of the work, and the prevailing fogs caused so great a loss of time, and, in addition, it was found so difficult to maintain operations with small boats during stormy winter weather in the crowded thoroughfares, that a seaworthy tug was finally secured and provisioned for a week's continuous work. In this way

Mr. Allen. floats were followed well out into the Lower Bay, and there was little loss of time.

In studying the circulation of water in New York Harbor the salinometer,* Fig. 65, proved to be an important adjunct, indicating at the same time the specific gravity of the water and its temperature, by which the proportion of "normal" sea water could be determined at once by reference to a diagram. By a series extending from the eastern end of Long Island Sound through the East River to the Upper Bay, for instance, it was shown by the high salinity east of Hell Gate that the waters of the Sound were not those which had come from the Upper Bay, where the Hudson River causes the proportion of sea water to drop to 60 or 70%, but were essentially those of the Atlantic entering from the east, and hence that there exists a definite net discharge to the west and south through the East River—a fact difficult to prove before Col. Black's more recent gaugings were made.

* "The Use of the Salinometer in Studies of Sewage Disposal," by Kenneth Allen, M. Am. Soc. C. E., *Journal*, Assoc. of Eng. Societies, April, 1911.

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PAPERS AND DISCUSSIONS

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PHYSICAL VALUATION OF RAILROADS.

Discussion.*

By Messrs. Maurice G. Parsons and J. Frank Aldrich.

Maurice G. Parsons, Jun. Am. Soc. C. E. (by letter).—Valuation, to-day, is the fashion, and rightly so, for only with absolute and complete knowledge of facts can justice be done either the consumer or the producer. Surely, this is a great subject, large beyond the ability of any one commission which has not the thorough support of the entire country and cannot rely absolutely on its assistants. The people, the corporations, and the Profession should most heartily welcome Mr. Wilgus' paper as an endeavor to clarify valuation views more fully and to secure the co-operation of all concerned. Mr. Parsons.

It is interesting to note that here, again, the much-discussed subject of depreciation has come up. There is, perhaps, more written on this phase of valuation than on any other, very largely because, like will-power, it is a sort of composite; depreciation is made up, in part, of red lead, stomach, philosophy, bookkeeping, obsolescence, and the methods of treatment throughout. This divergence of methods causes much trouble. Any one of several logical processes will give correct answers to the question of depreciation, although certain steps in one method may differ entirely from similar steps in another.

The author has approached the subject of physical valuation in the large, showing that it is not a question of so many yards of earthwork, so many tons of steel; but that all parts of a railroad must be combined, fused, and vitalized, that they must be made a single working machine. That, however, is not all; the mere inventory of the physical property (if one may broaden the discussion beyond the limit set by

* This discussion (of the paper by William J. Wilgus, M. Am. Soc. C. E., published in May, 1913, *Proceedings*, and to be presented at the meeting of October 1st, 1913), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

Mr. Parsons. the subject) is only a small part of the problem. Before a board can rightly take from one and give to another, it must have knowledge, not only of the physical value, but of the complete economic and financial history of the company. It must know the total cost of producing the commodity (which cost is at times greatly in excess of that of the physical plant) and the total profit derived from its sale. Promoters may embark in hazardous but necessary business during hard times, with the result of large financial loss in the early days; then again there may be absolutely no risk connected with the building up of the business. The development value may be practically nil. On the other hand, regardless of risks which have been taken, subsequent profits, whether great or small, may alter entirely the question of what equity the public has in the business. The real problem begins after the physical valuation is made, and necessitates a complete knowledge of the history of the company and of the financial and political situation during its life. As the physical value must be determined in a broad-gauge manner, so also the entire subject of rate-fixing goes deeper than mere consideration of physical value.

One question about which the writer has been thinking is: "Where may our theory of valuation lead?" May we not get back to the old labor theory of value, which held, for example, that if a man produced in one day a clock which kept perfect time, whereas another man labored equally hard for a hundred days in producing an inaccurate timepiece, this second man, nevertheless, was entitled to one hundred times as much wages as the first man. We cannot say that a utility is entitled to a fair profit on all the investment unless that investment has been wisely made, and we must judge past actions with leniency. On the other hand, although the best judgment may have been used, it is possible that business has almost entirely disappeared, and that the company is entitled to a rather high rate—to what the traffic will bear. Rates must bear some relation to the actual cash value of the service and to a proper return on judiciously invested capital. The germ of the solution of this question of policy (which allows a fair return on the actual investment which may be considered to measure the labor, and may bring us back to the old labor theory of value), is contained in the case of Smith *vs.* Ames, wherein it is pointed out that the rates as affecting the welfare of the corporation and the welfare of the people must be considered in the light of a complete history of all conditions. It is to be hoped that this general broad subject will be more elaborately discussed, for on that depends the fair rate. Necessary regulation of present-day business gets us into deeper water than the one-time automatic competition of small companies.

As the value of a property depends on the purpose for which the valuation is made, we have several sub-heads of valuation. First of

these may be mentioned the physical value, determined by any one of several methods. Next, we may place the development or intangible value, consisting of various items not properly appraisable under the head of physical value, such, for example, as promoter's profit, legitimate costs of franchise, legal and engineering expenses, certain property rights, present value of past deficits, etc. Thirdly, the business value is the net income capitalized at the current rate of interest. The fourth, or going, value is sometimes used synonymously for the development value, or again with business value. It seems, however, that this is in reality a value by itself, differing from those already mentioned, and that it can very properly be defined as the difference between the business value and what the same investment would earn in a bank. In other words, if a capitalist chooses to let his money lie idle—chooses to be unenterprising—he gets a certain amount of interest. If, however, he sees fit to invest this money in a business, to promote a project, guide it safely through the development stage, put it in a good running order, and make the organization as a whole a single living unit—a going concern—he is entitled to more interest; he is entitled to a fair return on the investment under the particular conditions which he has met and conquered, and the going value is that excess which the business earns over and above what the same money would earn had he chosen to leave it in a bank. The going value might quite properly be defined as the difference between the business value and the idle value. Mr. Parsons.

J. FRANK ALDRICH, ESQ. (by letter).—Mr. Wilgus' paper is the "last word" on this present-day subject, and although the writer will confine his remarks to a discussion of the land element involved, it is difficult to see how he is going to raise many issues in the field covered by this paper; for, after some ten years of experience by valuation engineers and a pretty general discussion of the subject, the author has succeeded in eliminating a vast amount of theory and undigested argument—going directly to the meat of the proposition—and from his record as a practical railroad builder and appraiser has evolved basic principles which are both logical and sound. The writer does not mean by this that the subject is beyond the realms of controversy in detail, but as to the hitherto mooted questions of reproductive value, overhead charges, depreciation, etc., the author is most convincing and in accord with the best authorities on the subject. Mr. Aldrich.

As with many propositions of professional interest, the opportunity exists for wide-spread discussion, which is sometimes carried to a point of beclouded mental vision. The sooner the subject reaches the practical stage—where justice to all concerned will be the key-note of discussion—the sooner will there be harmony of action between those who, on the one hand, are honestly striving to do exact justice to the general public, and those who, with equal zeal, represent the railroads.

Mr. Aldrich. With the railroads (it has been suggested) this public valuation is to be a "two-edged sword," for, if the result is satisfying as a basis for rate-making, how will it operate when it comes to matters of taxation? The writer does not agree with some authorities: that there cannot be one valuation for the one and another valuation for the other. Bear in mind that these remarks are confined, as closely as practicable, to the element of land values (no inconsiderable part of the whole), and when R. A. Thompson, M. Am. Soc. C. E. (one of the Board of Engineers recently retained by the Interstate Commerce Commission under the Adamson Act), asks: "Is there any logical reason why a valuation for this purpose [the issuance of stocks and bonds] should not also serve—as far as it pertains—as a basis for taxation or for regulating freight rates?" and again: "as far as the State is concerned and to be consistent should not one valuation serve all purposes?" the writer answers, to both queries, emphatically, "no"! If an individual or corporation decides to build a railroad, he, or it, must acquire a right of way, which it is conceded will cost per acre, through the country districts, from two to five times the normal acreage values of adjoining land. The fact that it costs this amount more, does not make it worth more, and it should be assessed (for taxation) at what it is worth, not at what it has cost. The reasons for its costing more to the railroad will not be discussed here, for that is now axiomatic and elementary. It is enough to say it does cost more, as every one who has had broad experience in buying right-of-way property for railroads knows; and it would be a gross injustice, as well as a blunder, to tax the strip of land used for right-of-way purposes at its cost, say, $100 per acre, when the adjoining land is assessed at $25 per acre.

Mr. Thompson cites the Texas valuation, where he says his experience as Appraising Engineer for more than 10 years with the Texas Railroad Commission confirms his belief that, in the absence of actual figures of cost, right of way and other real estate should be appraised at but little in excess of the market value of abutting property, and adds: "the conditions under which the railroads were built in Michigan, Wisconsin, Iowa, and Minnesota cannot have been radically different from those in the southern and western states."

Now, let us see: In the Michigan Appraisal* two illustrations are given to indicate the factor that should be used for reproductive values:

1.—The Pere Marquette Railroad, in Montcalm County, paid an average price of $135.19 per acre, and the 1900 appraisal showed an average of $29 per acre on the 918 acres appraised........Factor, 4.66

2.—The Grand Trunk Railroad paid $491.13 per acre for 63.2 acres, and the 1900 appraisal showed $61.44, or only one-eighth of the actual purchase price..Factor 8

Twenty-three illustrations in fourteen counties showed that the

* *Transactions*, Am. Soc. C. E., Vol. LXXII, p. 57.

average cost of lands was from 230 to 726% higher than the 1900 appraisal, and this, too, "after the 125% and fixed charges had been added" to the appraisal values. Mr. Aldrich

In Wisconsin, the late W. D. Taylor, M. Am. Soc. C. E., the State Appraiser, said:

"In farming lands, small towns, and suburban and residence property, the right-of-way value was taken to be 250% of the market value for other purposes," and notwithstanding Mr. Thompson's conclusion "that, in the absence of actual figures of cost, right of way and other railroad real estate should be appraised at but little in excess of the market value of abutting property."

Mr. Thompson says: "For rural property, the ratios used by Professor Taylor in the Wisconsin appraisal appear to be quite fair."*

In Minnesota, Appraiser Morgan's findings (after employing several special agents who made a study of transfers and assessed values over the State) were, that in the State at large, exclusive of the St. Paul, Minneapolis, and Duluth Terminals, a multiple of 3 was proper, while in St. Paul he used $1\frac{3}{4}$; in Minneapolis, $1\frac{3}{8}$; and in Duluth, $1\frac{1}{4}$.

Professor Taylor thought city property should be put in at 133% of market value in strips of 100 ft. width or less, and at 110% where the land was owned in blocks or in width greater than 100 ft. It is evident, however, that no "hard and fast" rule will apply to all parts of the country. Varying conditions appear along different lines, even in the same State. As stated by Henry Earle Riggs, M. Am. Soc. C. E.:†

"It is comparatively simple to fix within very close limits the reproduction cost of tracks, bridges, locomotives, or any of the other elements of physical valuations. Not so with the land."

And again:

"It is impracticable entirely to eliminate differences due to error of judgment on the part of appraisers. Where these differences do occur, experience must be the governing factor."

Were the records complete, an abstract of cost prices to the railroads, together with transfer considerations of adjoining land, and assessed valuations, the problem would be simplified, but, except in isolated cases, such records are not available, and the appraiser must be guided in large part by his or others' experience in the actual purchase of rights of way and other real estate for railroad use. He must be fortified with ample local testimony as to basic values and the individual knowledge of local real estate agents or railroad employees who have personal information as to actual transactions. When practicable, he should examine recorded transfers at the county seats for a number of years back, and take notes concerning the assessed valuations on properties contiguous to the railroad. All this collateral information,

* *Transactions*, Am. Soc. C. E., Vol. LXXII, p. 205.
† *Transactions*, Am. Soc. C. E., Vol. LXXII, p. 139.

Mr. Aldrich. including the names and addresses of local authorities, should be carefully preserved and indexed for ready reference. As Mr. Wilgus indicates—land valuations should be directed from one central head, from one whose experience in acquiring property for railroad use (whether by purchase or through condemnation proceedings) has given him the fundamentals which cannot be ignored in the fixing of reproductive prices.

The appointment of local appraisers has not resulted satisfactorily. Fixed opinions or local prejudices frequently exist among appraisers of good repute, and lack of harmony is bound to show in the returns. A well-drilled force of assistants, organized and directed by the chief appraiser, will produce the best results, and, as the author well says, "avoid the inconsistencies and errors which are common where the work is entrusted to a multitude of local men unversed in the broader aspects of the problem."

That problem is: What would it cost to reproduce for railroad purposes the land and other real estate now occupied by a given railroad—other conditions adjacent to and through the country traversed by it being as they are at present?

It is immaterial that the railroad itself may have been in large part responsible for the development which its own operation has brought to the surrounding property. It is inconceivable that the added values which have come to adjoining lands owned by A, B, and C should not be reflected in that owned by the railroad. The assessor certainly thinks it is. If you are in doubt about it, look up the record, for instance, of the increased assessment for 1913 on the terminal lands of the New York Central Railroad Company in New York City.

However, consider for a moment the question of "original cost" of rights of way. Unfortunately, the records of these purchases are not always—in fact are seldom—obtainable. In many cases they are not in existence, so that, to make any practical, general use of such data is out of the question; and, if they were available, their examination and tabulation would involve an amount of labor hardly commensurate with their importance to this subject. It will be interesting, however, to give a few examples which illustrate the elements to be reckoned with by the buying agent when he undertakes the purchase of rights of way. A recent case is that of a road now under construction just over the border line of Canada, which is not dissimilar to some of those on this side of the line. The road in question is to run along the north shore of Lake Ontario—through a fruit belt of much the same character as that traversed by a railroad on the south side of the same lake. The writer was considerably puzzled in fixing the reproductive values along the latter line, for there was but little information available covering the original purchases. The writer's assistant in that work was engaged later in valuing the right of way of the railroad on the north

side of the lake and had access to the records of purchase. The twenty-five examples, Table 1, are from that record. The right-of-way agent states that his estimate indicates that the cost of the entire right of way will average between six and eight times the normal value of the adjoining land. Mr. Aldrich.

In the examples given in Table 1, improvements and what may be termed consequential damages are alone considered. The names and addresses of owners are known, but are omitted from the table.

If the true values of the land alone were represented in these data, the reproductive value would be represented by the percentages given, which, it will be noted, run from 200 to 800, but the right-of-way agent assures us that the prices allowed for the land alone were fully double their normal value.

It may be said that these are isolated cases, and represent but a small percentage of the entire right of way. This is true in part, but the percentage is not as small as might be supposed, on the other hand, not one of them was a condemnation case. Every one was a purchase, in which an agreement was readily reached between the buyer and the seller. Many owners are holding out for extravagant figures, and condemnation proceedings will follow; commissioners must be paid, and attorneys' fees will add to the expense. The railroads seldom "get the best of it" in cases of this kind, so that we may fairly conclude that the right-of-way agent's estimate of 600 to 800% in this instance fairly indicates the ultimate cost to the company.

A case in point to illustrate how difficult it may be for the appraiser to arrive at a fair value—or rather cost—of right of way, came under the writer's notice in appraising the lands of the West Shore Railroad in 1911. His assistant had gone over the road in advance, and reported an average valuation of the lands between West Haverstraw (north of Haverstraw proper) and Cornwall at from \$100 to \$300 per acre, basic, and had placed a reproductive value on it at from \$300 to \$750 per acre. The writer questioned his figures, and went into the matter carefully. Much of this right of way runs along the Hudson River at the foot of precipitous mountain sides—in fact, practically all of that which is in Orange County. Railroad construction there was most difficult. Above West Point there would seem to be but little actual value in the land. Fortunately, the writer was given access to the records of purchase (made in 1886) and was dumbfounded to find the total cost of these lands to be as given in Table 2.

The explanation of the high figures in Table 2 is to be found largely in the consequential damages due to severance, as the river was cut off from large estates by a railroad right of way at grade.

Another example which came under the writer's observation was on the Lehigh Valley Railroad near the Town of Wysox, Pa., where it became necessary to buy a house and lot to gain an additional 20 ft. of

Mr. Aldrich.

TABLE 1.

Example No.			Total cost.	Percentage.
1	3.15 acres of land	$200.00		
	Fruit trees	300.00		
	Moving house and shed	350.00		
	(Crossing reserved)		$800	$400
2	Land	300.00		
	2 wells	125.00		
	Moving house and shed	525.00		
	(Crossing reserved)			
	Fruit trees	250.00	1 200	400
3	1.67 acres of land	125.00		
	Angling field	100.00		
	Water cut off	50.00		
	Trees	75.00		
	(Timber reserved)		350	280
4	2.25 acres of land	135.00		
	Drainage, 80 maple trees	215.00		
	Angling farm	100.00		
	(Timber reserved)		450	333
5	1.55 acres of land	116.00		
	Angling farm	100.00		
	Water cut off	125.00		
	Moving fence	9.00		
	(Farm crossing)		350	300
6	3.3 acres of land	247.50		
	Angling farm	100.00		
	Water cut off	150.00		
	In lieu, farm crossing	52.50	550	222
7	1.75 acres of land	131.25		
	Severance from water	125.00		
	Angling farm	100.00		
	Fall wheat	13.75	370	282
8	3.6 acres of land	360.00		
	Angling—4 fields	200.00		
	Water cut off	150.00		
	Shade trees	40.00		
	(1 farm crossing)		750	208
9	1.5 acres of land	150.00		
	Angling and changing fences	150.00		
	Water cut off	150.00	450	300
10	Land	200.00		
	Water cut off	100.00		
	Crossing inconvenience	200.00		
	Rocky land—crossing reserved		500	250
11	5.75 acres of land	550.00		
	40 apple trees	900.00		
	Gravel pit	50.00	1 500	273
12	2 acres of land	200.00		
	House and shop	600.00		
	80 trees	1 600.00	2 500	833
13	Land	100.00		
	10 apple trees	250.00		
	5 plum trees	60.00		
	Moving barn	50.00	460	460
14	Land	100.00		
	Apple trees	280.00	380	380

Mr. Aldrich.

TABLE 1.—(*Continued.*)

Example No.			Total cost.	Percentage.
15	House and land	$150.00		
	26 fruit trees	450.00	$600	$400
16	1.72 acres of land	525.00		
	Apple trees	1 080.00		
	Berry patch	395.00	2 000	381
17	3.03 acres of land	600.00		
	Apple trees	900.00	1 500	250
18	1.53 acres of land	200.00		
	Apple trees	450.00		
	In lieu, farm crossing	50.00	700	350
19	1.15 acres of land	150.00		
	Apple trees	250.00		
	Berry bushes	50.00		
	In lieu, farm crossing	50.00	500	333
20	3.17 acres of land	455.00		
	Water	300.00		
	Inconveniece	145.00		
	Crossing railway	100.00	1 000	220
21	1.5 acres of land	210.00		
	Apple trees	175.00		
	Strawberries	150.00		
	Damages	65.00	600	286
22	3.1 acres of land	465.00		
	In lieu, farm crossing	100.00		
	Deep cut through orchard	158.00		
	66 large apple trees	1 452.00		
	25 small apple trees	175.00	2 350	505
23	Land, 3.95 acres	450.00		
	Damages for cutting off water	350.00		
	Damages for crossing track	200.00	1 000	222
24	1.37 acres of land	400.00		
	House	300.00		
	35 apple trees	250.00		
	Well	100.00		
	Removing barn	80.00		
	17 plum and pear trees	70.00	1 200	300
25	0.92 acres of land	200.00		
	27 fruit trees	540.00		
	Strawberries	100.00		
	Damages to building	160.00	1 000	500

TABLE 2.

Town.	Acres.	Cost.	Average cost per acre.
West Haverstraw	22.45	$56 195	$2 500
Stony Point	104.77	187 670	1 800
Highland	105.26	183 985	1 800
Cornwall	35.78	71 530	2 000

Not any of this land is in West Point, which is a Government reservation. This company occupies under a lease from the General Government.

Mr. Aldrich. width for the right of way. The sum paid for this property was $10 000, and the house with the remainder of the property was sold for $5 000, making the 20-ft. strip (worth normally perhaps $500), cost the Railroad Company ten times its actual value. "Consequential damages," it will be perceived, is no small matter in railroad construction. A whole chapter might be given to this subject in view of the important and growing demand for the elimination of grade crossings. One example alone, which came under the writer's notice, may suffice for illustration. The New York Central Railroad paid, as its share, $3 132.98 and $32 592.87, respectively, for these eliminations at Seneca Street and William Street, in Buffalo. The total awards for these two crossings amounted to $7 531 and $65 185.63, respectively.

"Franchises and Street Crossings" is another branch of this subject to which much space might be given, but it is not the intention at this time to discuss any of these matters extensively. The writer has tried to give, as briefly as possible, some of the reasons "for the faith that is in him," and has given a few examples which have come to him through experience in this work to justify that faith.

The commonly accepted method of arriving at franchise value, through gross earnings and revenue, will hardly apply to railroad corporations, and it is perhaps of questionable propriety that any account should be taken of corporate franchise when applied to its charter. With this the writer has nothing to do; but, to ignore the element of value which applies to local franchises or rights to occupy or cross streets and highways, or even streams, would hardly be sound. Has the Park Avenue franchise, granted many years ago to the Harlem Railroad for an entrance into New York City, no appraisal value? Has the franchise which permits the New York Central and Hudson River Railroad Company to occupy Washington Street, Syracuse, for a distance of 1.2 miles no value?

The cost of a private right of way through either New York City or Syracuse, at the time these rights were granted, would have been comparatively insignificant. What is the right of way through the heart of Syracuse worth to-day, and how many millions of dollars would it take to purchase a private entrance to 42d Street from the Harlem River (more than 4 miles) if it had to be bought to-day? It might have been acquired for considerably less than $1 000 000 then —could it be duplicated for $25 000 000 now? Is genius and foresight to have no credit for risks of failure taken fifty or more years ago? Should capital invested in this particular line of business be singled out for attack and be deprived of the same natural benefits which come to other investments made in the same period?

The general rule to be followed in arriving at a just value of the space occupied by a railroad, at a street, or highway, or navigable stream crossing, is to multiply the average value of the abutting prop-

erty on both sides by the area and divide by two, on the theory of joint occupancy by two interests—the public and the railroad. If the crossing be occupied by three interests (whether at grade or otherwise) then the divisor is 3, and so on. The same rule will apply to street or highway occupancy along and through the streets, unless sole occupancy of a given space is enjoyed by the railroad, when, if the right is perpetual, full value is taken. Mr. Aldrich.

Rights of way along and through streets, not at grade, should be estimated at one-third the value of the surface land.

These rules are quite general, and have been adopted as the result of careful thought and analysis growing out of study and experience in this feature of the work. All crossings not at grade are attended by increased cost of construction to the railroads, and, if at grade, the cost of watchmen, or otherwise safeguarding them, puts an added burden on the railroad. If further justification be needed for including a value for public crossings in this estimate, it should be remembered that revenue is based on mileage to a large extent, and that, therefore, the value of every foot of right of way should be properly considered in some logical manner.

As to what lands, if any, owned by a railroad company are to be eliminated from consideration—in the matter of rate-making, for instance, the appraiser has nothing to do—that is a question for the Interstate Commerce Commission and the railroad company to settle. It is the appraiser's business to appraise all the lands of the company, and, in fixing his value, to differentiate between lands actually in use or needed for the operation of the railroad, and those which have been abandoned, such as depleted gravel pits, parts of original right of way, and even where surplus land has been acquired for future yard extensions.

It may be contended, for instance, that houses erected by the company, or purchased by it, for housing employees in the vicinity of shops or transfer yards, is not real estate proper to be included in a valuation for rate-making or of consideration in the issuance of the company's securities. However that may be, it will not affect the method to be used in its appraisal. It is "outlying" property, in any event. The company would not be confined to one particular location for such facilities, and its reproductive value would be the bare value of the land and the present depreciated (if any) value of the houses. Exhausted gravel beds or abandoned right of way would in most cases have but nominal value. Many similar instances could be mentioned, but common-sense judgment in most instances will govern. Large tracts of land purchased for yards, water supply, etc., are ordinarily acquired at a smaller figure, relatively, than right-of-way strips; on the other hand, "plottage" is an element to be considered, particularly in cities, so that no fixed rule will apply.

Mr. Aldrich. The question of land or money donations can be disregarded, for two reasons: First, because property is property always, and whether the railroad company or an individual has acquired lands without monetary consideration, or at a low figure, or as part consideration for the risks of investment, its value is an entity and cannot be ignored, either by the assessor or by the stockholder. Second, the practice of donations is a thing of the past—and we are dealing with the present. As part of the "original cost"—that is another proposition. There is no special rule for appraisal based on population that will apply. This will be disclosed by conferences with real estate men in different parts of the system. The attitude of owners will be found to be widely different in different places, but it will be found to be very nearly axiomatic that the more valuable the land required, the less the size of the factor which should be used to indicate its reproductive cost. This becomes evident when the company negotiates for a right-of-way strip through waste lands. An acre held by an owner here, or a few acres by another owner there, may be worth only $5 or $10 an acre, but, unless the wily farmer can get $50 per acre, it will, as a rule, go to condemnation, where the expenses will surely bring the cost up to the holding price.

Before leaving this subject, the writer should perhaps mention one or two additional examples to illustrate what has preceded. The normal value of land in Jersey City, where one of the shorter branches of the Lehigh Valley Railroad crosses the main line of the Pennsylvania Railroad, is 60 cents per sq. ft., but it cost the former company $3 per sq. ft. to acquire an easement under the latter line (through Court proceedings, if the writer remembers correctly), and later the Pennsylvania Railroad Company paid the same price for a portion of the Lehigh Valley property at the same point.

At another point, in Bayonne, it cost the Lehigh Valley Railroad $1.50 per sq. ft., when the normal values at that point were 25 cents per sq. ft. In Joliet, Ill., the following case came under the writer's observation: The right of way of the Rock Island Road was relocated, and it became necessary to tear down a 5-story hotel building, worth approximately $100 000. An appraiser, going over the line in later years, might have no knowledge of this, and no consideration would be given to it, yet it was a part of the cost to that railroad. In fact, other buildings at this point were either totally obliterated or there were consequential damages amounting to several hundred thousand dollars; and these are by no means isolated cases. Therefore, if the records were in all cases intact, a valuation based on "original cost," would be quite as satisfactory to the railroads as any reproductive valuation that could be made.

There are other elements of interest which enter into a proper consideration of the question. The rather perplexing problem of fixing

a fair valuation on docks, piers, and water-front terminals will not be discussed at this time, nor the asset value of the virile railroad organization, which only time and a high order of executive control develops. Mr. Aldrich.

The "Physical Valuation of Railroads," as a science, is still in its infancy. The Courts probably appreciate this, and will no doubt be influenced in their rulings by the results which, as time goes on, will be worked out by engineers and students who are giving their time to the solution of these problems.

The Supreme Court decision in the Minnesota Rate Case was announced just as the foregoing had been written, and, after a careful reading, the writer finds no good reason for changing the views which he has just expressed. It does not seem possible that the land features involved could have been properly presented to the Court. Like others who have discussed this problem, it does not differentiate between the terms "Value" and "Cost." The Court says:

"It is at once apparent that, so far as the estimate rests upon a supposed compulsory feature of the acquisition, it can not be sustained," and again, "it is also said that this price would be in excess of the present market value of contiguous or similarly situated property," but (it adds) "supposing the railroad to be obliterated and the lands to be held by others, the owner of each parcel would be entitled to receive on its condemnation its fair market value for all its available uses and purposes," and:

"Moreover, it is manifest that an attempt to estimate what would be the actual cost of acquiring the right of way, if the railroad were not there, is to indulge in mere speculation" and "the values of property along its line largely depend upon its existence" and, finally, "the assumption of its nonexistence, and at the same time that the values that rest upon it remain unchanged, is impossible and can not be entertained."

All of these arguments, with the exception perhaps of that contained in the last stanza, have been anticipated, and have been fairly met in the writer's consideration of the subject up to this point. There is force in the proposition that values based on present conditions might not obtain, in the event of the non-existence of the right of way. The argument is that the railroad, having been long established, has created values based on its very existence. Their determination, the Court holds, would be "wholly beyond reach of any process of rational determination." Much might be said on this phase of the question, but, the writer thinks, it is susceptible of demonstration that, as a rule, railroad terminals in cities tend to depreciate the value of contiguous property. Good examples of this may be found in Chicago and Buffalo, where real estate men know that the least desirable—and consequently those which have the lowest values—are those properties which surround the railroad terminals. The writer knows of no city, in fact, where this does not apply.

Mr. Aldrich.

The location of a railroad right of way through the country is usually determined by natural laws, and the farm values affected by its construction extend, ordinarily, for some distance on either side of it, but farmers state that the effect of the building of the right of way immediately adjacent to their property is to depreciate its value, and testimony of this nature is commonly accepted in condemnation proceedings.

Heretofore, the generally accepted theory has been that reproductive values should be based on the present market value of contiguous property, plus whatever increment experience and available data might indicate as proper to add to bring it up to its actual cost to the company. Subject to any further review of the question by the Court of last resort, its recent decision must stand, but this does not preclude testimony as to actual cost. The unfortunate situation is thereby created, however, of making it possible for a company owning a line constructed in recent years to produce and get the benefit of such testimony, while the records of older lines may not be available. Records of land purchases for many of the Southern roads, for example, are said to have been destroyed during the Civil War.

A valuation of these properties, based on market prices of adjoining lands, might and probably would result in great injustice to them. The Court refers to this added increment as one "over all outlays of the carrier and over the values of similar land in the vicinity," and says:

"It is an increment which can not be referred to any known criterion, but must rest on a mere expression of judgment which finds no proper test or standard in the transactions of the business world. It is an increment which in the last analysis must rest on an estimate of the value of the railroad use as compared with other business uses."

Herein, the writer thinks, the Court is again at fault, if it applies the principle to railroad valuations generally. In the important railroad land valuations made by the writer, he has never considered "railroad use" as an element of valuation, nor has he heard that term used in this connection. It is not railroad use, it is not alone value, but it is cost that justifies the use of the added increment in making these appraisals. The latter are not used to cover "hypothetical outlays," as the Court asserts, but are based on sound reasoning born of experience and fortified with enough, if not all, actual cases to justify this conclusion.

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THE ABSORPTION OF OXYGEN BY DE-AERATED WATER.

Discussion.*

By Messrs. W. E. Adeney and Earle B. Phelps.†

W. E. Adeney, Esq. (by letter).—In this paper Professor Phelps does not offer any additional experimental evidence in support of the formula which Col. Black and he, in their Joint Report of 1911 to the Board of Estimate and Apportionment, have proposed for calculating the rate at which de-aerated waters become re-aerated, when exposed to natural conditions, in terms of time, depth, initial dissolved oxygen content, and the diffusion coefficient of dissolved oxygen in water. Mr. Adeney.

The fundamental conception underlying this formula is that the re-aeration of de-aerated waters is effected by the absorption of oxygen by the layer of water exposed to the air; that the subsequent transmission of the dissolved oxygen throughout the underlying masses of water takes place strictly in accordance with Fick's law of diffusion; and that, as far as appreciable effects are concerned, no other natural agency or factor need be considered.

The only experimental evidence, which the authors have advanced in arriving at their proposed formula, are some figures, which they have put forward as indicating the diffusion coefficients of dissolved oxygen in distilled water at certain stated temperatures. These figures have been determined by a method which the authors of the formula designed especially for the purpose, but the working details of which have only been slightly indicated in the report referred to.

The experimental difficulties in the way of determining accurately the coefficients of dissolved gases in water are very great, and Hüfner, so far as the writer knows, is the only observer, among the few who

* This discussion (of the paper by Earle B. Phelps, Assoc. Am. Soc. C. E., published in March, 1913, *Proceedings*, but not presented at any meeting), is printed in *Proceedings* in order that the views expressed may be brought before all members.

† Author's closure.

Mr. Adeney.

have ventured into this field of investigation, who has endeavored successfully to overcome the most serious of these difficulties.

The writer has already pointed out, in Section II of the Report which he had the honor of presenting to the Metropolitan Sewerage Commission of New York in 1911, that the method in question does not determine the diffusion coefficient, but the rate of re-aeration of the water experimented with by quite a different factor, that is to say, by the downward "streaming" of dissolved oxygen from the exposed surface of the water; and, inasmuch as the water used by Col. Black and Professor Phelps in their experiments was not distilled, but contained decided quantities of mineral matters in solution, this "streaming" process must have been very rapid, with the result that the values which they obtained for the diffusion coefficients in distilled water were very much too high.

A rough estimate of the relative rates at which columns of de-aerated sea water may become re-aerated, by (*a*) downward "streaming" from the surface exposed to the air, and (*b*) by true diffusion in accordance with Fick's law, may be obtained from the results of an experiment which the writer has described, as follows:*

"A U-shaped tube, each limb 1 600 mm. long and 50 mm. diameter, was filled with boiling sea water and immediately closed air-tight with indiarubber corks. When the water had cooled, the tube was further exhausted by means of a mercury pump. One limb was then uncorked, and the water in it saturated with atmospheric gases by a current of air drawn through the surface-layer to a depth of 50 mm. for 48 hours. After this, a sample was drawn from the bottom of the open limb, and one from the lower portion of the closed limb, about 200 mm. from the bottom. The gases were extracted from these and the nitrogen in each determined, with the following results [expressed in cc. at 0° C., and 760 mm. bar., per liter]:

Open Limb.	Closed Limb.
12.12	1.49

Six months later another sample was collected from the lower portion of the closed limb, as before, and the nitrogen in it determined; it was 1.73."

These results show clearly that, though the re-aeration of a column of de-aerated sea water, 1 600 mm. deep, and of uniform density, is relatively rapid, so that it may be completely saturated with air in 48 hours when evaporation freely occurs from the surface, it is so extremely slow when dependent on simple diffusion, that it may be altogether neglected in considering questions of the re-aeration of sewage-polluted tidal waters. It may be noted that the temperature of the laboratory during the first two days of the experiment described varied between 10° and 12° cent.

* Section I in Appendix VI to the British Royal Commission's Fifth Report, p. 60.

Mr. Adeney.

Professor Phelps himself has admitted that his method is faulty. On page 346* he states in reply to the writer's criticisms:

"There are admittedly imperfections in the process, and the results are not of extreme scientific accuracy. For this reason, the work, which was originally carried out as a contribution to pure science, was not published as such."

By way of self-defense, he continues to remark that the accuracy of the method is sufficient "for an engineering discussion involving so many unknown factors, as does the New York Harbor problem."

Surely, the problem of determining accurately the diffusion coefficients of dissolved oxygen in water cannot be placed under the category of "involving so many unknown factors." The conditions necessary for the accurate determination of the diffusion coefficients in question are certainly quite well understood, although it may not be easy experimentally to ensure them; and, inasmuch as the whole superstructure of the formula depends on the accurate determination of these diffusion coefficients, the writer ventures to express the opinion that Professor Phelps would have been well advised had he submitted a detailed description of his method to the consideration, in the ordinary way, of his brother chemists, before applying it to the solution of a problem of such wide and far-reaching importance as that of New York Harbor, affecting, as it does, the well-being of many millions of people, as well as the interests of a vast and rapidly growing commercial center. Had he done so, he no doubt would have had the benefit of the criticisms of other workers, and would not have been left long in doubt as to the nature of the "unknown factor" which has vitiated his coefficient determinations. The writer ventures to think that he has given the true explanation of this unknown factor, in his criticisms† of the method, in which he has shown that the experimental basis of that method is quite erroneous.

Professor Phelps complains (page 351*) that the writer has not suggested a general expression applicable to the calculation of the average rate of re-aeration of tidal waters by "streaming." This was not done, because, to have attempted anything in the way of a working formula for the purpose, he would have had to follow the very undesirable course of making broad assumptions, for which there exists at present no scientific basis. In fact, he would have had to follow the course which he complains that Col. Black and Professor Phelps have adopted in arriving at their proposed formula. The writer is quite willing to admit that such a course would be warranted for the purpose of raising a discussion on the question, if restricted to purely scientific interest, but certainly not in connection with one of such

* *Proceedings*, Am. Soc. C. E., for March, 1913.

† Report to the Metropolitan Sewerage Commission of New York, 1911, p. 83.

Mr. Adeney.

vast practical importance as that of the powers possessed by the tidal waters of New York Harbor for the disposal of sewage matters, within limits of safety to public health, and to the amenities of their surroundings.

The writer has preferred to follow the usual custom by publishing a description of his experiments on "streaming," although they were simply pioneering experiments, and has to acknowledge that he has received the benefit of some helpful criticism from Professor Phelps. He gladly takes this opportunity of expressing his appreciation and thanks for that criticism. The writer has also to express his indebtedness to Professor Phelps for pointing out that the results of his experiments do not bear the precise and general value that has been placed on them by some writers in the United States, because, as already stated, they are only of a pioneering character, and are necessarily only true for the conditions of the particular experiments described.

The fact, however, that the proposed formula rests on an erroneous experimental basis, is not the only serious objection that may be urged against the position that has been taken by Col. Black and Professor Phelps on this question of re-aeration.

With reference to the particular question of the re-aeration of tidal waters, Professor Phelps assumes that the same factors obtain with sea water as with fresh water, and that it is effected solely by diffusion, according to Fick's law, from the exposed surface downward.

According to Professor Phelps' strongly expressed opinion, however, the surface layers of inshore tidal waters are fresher by reason of admixture with land waters, and, therefore, less dense than the heavier salt water below. In other words, the layers of water concerned in actually dissolving oxygen from the air, for subsequent diffusion below, are less dense than the lower layer of the water. Notwithstanding this, Professor Phelps assumes that diffusion will proceed according to Fick's law, just as it would were the water of uniform density throughout its depth. Again, he gives no experimental data in proof of this, and the writer knows of none himself. In the absence of direct evidence to prove it, Professor Phelps is not justified, in the writer's opinion, in stating that, because Fick's law holds good for the diffusion of dissolved oxygen in a liquid of uniform density, it must necessarily do so in one increasing in density in the direction of diffusion. Under these circumstances, the writer is entitled to hold the contrary view.

One further assumption, which Col. Black and Professor Phelps make, demands notice. It is stated on page 56 of their original report, and is as follows:

"Since the fundamental law of aeration is one of diffusion, and, furthermore, since the surface of any body of water is practically

saturated at all times, it must be evident that no mere surface action can by itself affect the rate of diffusion." Mr. Adeney.

No experimental evidence of any kind is given in support of this statement. The question is one on which the writer has made a considerable number of experimental observations since he published the description of his pioneering experiments on "streaming," all of which prove beyond doubt that the surface of a body of water, when exposed to atmospheric conditions, does not become saturated at any time as long as the layers immediately below it remain only partly aerated.

The writer has definitely found, by careful experimental observations, that, as oxygen is dissolved by the surface of any quiescent body of water, when de-aerated or only partly aerated, it passes practically as quickly downward through the lower layers, so that the surface does not become saturated until the dissolved oxygen content of the layers below it approach the condition of saturation.

He has found this to be true both of fresh water and of sea water. The only marked difference between the two is that in the sea water the transmission downward is quicker than in fresh water, when the surfaces of the two bodies of water are exposed to the air so that evaporation can take place freely from them; and *vice versa* when the conditions are such as to prevent evaporation from the exposed surfaces.

The writer has also found that when the surfaces of de-aerated columns of fresh water are exposed to the air, so that evaporation can take place freely from them, and when the columns themselves are maintained at a constant and uniform temperature, the downward distribution of the dissolved oxygen is so nearly uniform, for depths of about 1 000 mm., that the oxygen content of the water at that depth has been found to be nearly equal to that of the surface layer at various stages during the process of re-aeration.

Professor Phelps admits the correctness of the writer's observations on "streaming" in his experiments with columns of sea water, but assumes that "streaming" does not affect the practical question of the re-aeration of tidal waters, because it was caused, as he explains, in the case of the writer's experiments, by the formation of concentrated layers of water, the result of evaporation from the exposed surfaces of the experimental columns; and he assumes that the "streaming" would not occur in tidal waters, when the surface layers are fresher and, consequently, denser than the lower layers of sea water.

Again, Professor Phelps gives no experimental evidence in support of this assumption, and, in the absence of definite evidence, he is no more entitled to make it, than he is to assume that diffusion will occur according to Fick's law under the same conditions.

Mr. Adeney. The writer has already pointed out that if a marked stratification obtains in a tidal water, and the land water lies on the surface of the sea water, the sewage matters, which are themselves carried by fresh water, will gather to the surface layer also and will there be re-aerated chiefly by "streaming."

The New York Harbor waters, however, are not thus stratified. The Metropolitan Commission states:*

"The general configuration of the bottom and of the main channels of the harbor is such as materially to aid in keeping the water well mixed. * * * The water is usually more saline at the bottom than at the top, but the difference is usually slight and there is apparently no sharp line of demarcation."

Professor Phelps would be justified, no doubt, in assuming that "streaming" would not extend to the lower layers of a tidal water, the surface layer of which consisted practically of wholly fresh water, and the lower layers of undiluted sea water, but he is certainly not justified in assuming, without experimental observation, that it would also not occur in tidal waters in which, as in New York Harbor, the water at a depth of 20 ft. contained, on an average, only 6% more sea water than at the surface. The experiments which the writer has made certainly do not justify such an assumption.

The writer does not think that any useful object can be attained by following Professor Phelps in his detailed discussion as regards so-called calculated and observed results, because, until the scientific basis on which such a discussion can be usefully carried on has been definitely settled, it can only be juggling with figures to attempt to do so.

In his Report to the Commission (page 81), the writer has mentioned the chief factors, as far as they are known, which are concerned in the re-aeration of tidal waters exposed to natural conditions, and gives reasons for believing that:

"The rate of re-aeration must therefore be an extremely variable quantity from day to day, and even from hour to hour."

Again, on page 87, he states:

"It is quite evident that under their combined influence [*i. e.*, the factors concerned in re-aeration] the rate [of re-aeration] may vary practically from zero to a value of such magnitude as to be of great practical importance especially during summer season.

"It need scarcely be pointed out, however, that a good deal of work has yet to be carried out, both in the laboratory and on the open water, before a definite value can be put to the extreme rate at which re-aeration under the most favorable conditions would occur, or even to the average rate—both would certainly vary with different classes of inshore waters."

*1912 Report, pp. 26 and 27.

Earle B. Phelps, Assoc. Am. Soc. C. E. (by letter).—The writer wishes to thank Dr. Adeney for his frank criticism, which makes it possible to define clearly the points at issue. There is apparently complete agreement on the two propositions that diffusion alone is of no material advantage in the re-aeration of polluted tidal waters and that the phenomenon of "streaming," if it takes place, effects re-aeration to a material extent. This being the case, further discussion of the accuracy of the determination of the diffusion coefficient becomes irrelevant. The writer sees no reason to alter his opinion that figures of this degree of accuracy, although admittedly too imperfect for use in a journal of physical chemistry, still have a legitimate use, especially when the probable magnitude of the error is stated. A review of the original data, in the light of the criticism made, leaves the writer still of the opinion that Fick's law holds in this case, that the mathematical analysis of the problem is sound, and that the value of the coefficient as determined has a degree of accuracy better than that obtaining in other important engineering values that enter the problem, such as the measurement of stream flow and of sewage. Mr. Phelps.

There remains, however, as relevant to this discussion, the single question: "Does streaming take place in New York Harbor?" Dr. Adeney apparently accepts the writer's explanation of the nature of the streaming phenomenon, so far as saline waters are concerned, in that it is a gravitational movement of the more dense layers produced at the surface by evaporation. He objects, however, to the "assumption" that this process is not taking place in a body of water in which the density actually increases from the surface downward. Surely this is more than an assumption, and it calls for no experimental proof that lighter layers of water will not sink through heavier layers by the action of gravity. The quotation from the Metropolitan Sewerage Commission's report is not a sufficient basis for the statement that the waters are not stratified, if by stratified we understand an increase of density downward. The figures and diagrams of that report show such a condition almost universally, and the writer's experience, in the Charles River Basin at Boston, and elsewhere, indicates such a condition to be normal in estuary waters. Whether the density gradient be great or small, and whether or not there be a distinct line of demarkation (which is often found), the mere existence of a density gradient downward is obviously incompatible with a downward gravitational streaming of water.

Dr. Adeney does an unintentional injustice to our formula when he states at the outset that it determines the rate of aeration in terms of time, depth, initial dissolved oxygen content, and diffusion coefficient; and (later) that "no other natural agency or factor need be considered." A study of the method of using the formula will show that the time factor is the mean time between uniform mixings, and that

Mr. Phelps.

for its determination one must know all the physical conditions and natural agencies that assist in mixing the water, such as wind, tidal mixing, and the effect of passing boats. This work is now being extended by the determination of the time factor for streams of various types. Knowledge of this factor will make it possible to determine the rate of re-aeration of such streams. The formula has already been made use of in this way by the experts of the Royal Sewerage Commission of Great Britain, in its Eighth Report. The results show at once that the possibilities of re-aeration in such streams are far greater than in the case of deep estuaries.

The writer cannot agree that the correspondence between calculated and observed results in New York Harbor is only a "juggling with figures." The calculated results are based on the practical negligibility of re-aeration. The fact that they agree to a remarkable degree with the results of an extensive series of analyses made during the following year is certainly the most desirable kind of "additional experimental evidence," the absence of which Dr. Adeney regrets so keenly. If these calculations had been made by omitting all reference to re-aeration, the results would not have been altered materially. They do not involve any of the disputed points, and, without further reference to the other matters, they alone show the practical non-importance of re-aeration in New York Harbor.

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EXPERIMENTS ON WEIR DISCHARGE.

Discussion.*

By Messrs. Francis F. Longley, and W. G. Steward and J. S. Longwell.†

Francis F. Longley, Assoc. M. Am. Soc. C. E. (by letter).—The authors of this paper state that the experiments "were made, not with the idea of obtaining new general formulas for weirs, but for the purpose of testing the general weir formulas and ascertaining whether they are applicable to the weirs on the Boise and other projects of the Reclamation Service." Mr. Longley.

One of the most conspicuous features of this paper is the great difference that is noted between the measured quantities and the quantities as computed by old established formulas. Without some further analysis, this is likely to leave the false impression in the minds of those who are not well acquainted with the unparalleled researches of Francis, Fteley and Stearns, and Bazin, that their work was all for naught, and therefore a word regarding the recognized limitations of their formulas is in order.

In the measurement of water by the flow over weirs, one of the factors which may become very uncertain if its limitations are ignored is the matter of end contractions. Perhaps the most convenient form of weir is a sharp-edged notch in a vertical thin plate, which gives a stream with the ends fully contracted. Because of its convenience, this form has been studied by several able investigators in connection with other weir studies, and it is interesting to note their comments on the limitations which must be kept in mind in dealing with end contractions.

* Continued from April, 1913, *Proceedings*.

† Author's closure.

Mr. Longley.

The late James B. Francis, Past-President, Am. Soc. C. E., in his "Lowell Hydraulic Experiments", states:

"It is assumed * * * that the quantity discharged by a weir is directly proportioned to its length; this, in weirs having complete contraction, is, however, known not to be true, in consequence of the contraction which takes place at the ends of the weir.

* * * * * * * *

"It has been stated that the proposed formula is applicable only to weirs having a considerable length in proportion to the depth of water running over them. It is found by experiment that, when the length equals or exceeds three times the depth, the formula applies; but in lengths less than this in proportion to the depth, the formula cannot be used with safety.

* * * * * * * *

"* * * In weirs of very short length in proportion to the depth, the effect of the end contraction * * * influences the discharge to a certain distance, A, from the end of a weir; if the whole length of the weir is greater than 2 A, the effect of the end contraction is independent of the length; but if the length is less than 2 A, the whole breadth of the stream is affected in its flow by the end contractions, and, consequently, the proposed formula would not apply.

"In practical applications, this will seldom be an inconvenience, as it is nearly always practicable so to proportion the weir that the length may not be less than three times the depth upon it; if, however, there is no end contraction, the proportion of the length to the depth is not material."

Messrs. Fteley and Stearns developed their formula* to represent the discharge over a weir unaffected by end contractions. They conducted some careful experiments on the effect of end contractions, but state that:

"The chief value of these experiments consists in the warning they give that this form of weir should be avoided in cases where the most accurate results are desired."

M. Bazin, in connection with his researches on this subject, mentions, as one of the uncertain elements that must not be disregarded, the lateral contraction, which, though unimportant in weirs of great length, seriously modifies the results in shorter weirs.

In the extensive experiments carried out at the Cornell University Hydraulic Laboratory in 1899, for the United States Board of Engineers on Deep Waterways, weirs without end contractions were used, both for the standard and the experimental measurements, owing presumably to the uncertainty that would probably result with contracted weirs, at the rather high heads that were to be used.

In short, it is generally accepted that uncertainty results from disregarding the recognized limitations of end contractions. Within

* *Transactions*, Am. Soc. C. E., Vol. XII, p. 111.

these limits, data are at hand for making a satisfactory correction for the effect of end contractions. The controlling condition is as set forth in the statement quoted from the "Lowell Hydraulic Experiments," which is in effect that the influence of the end contraction must not extend to the middle of the weir. The law governing the extent of this influence is not known, but Francis considered it unsafe to use a head on the weir greater than one-third the length of the crest. Mr. Longley.

Disturbance of stream lines sometimes extends to a surprising distance from the source of the disturbance, as note the familiar experiment of the faucet and the knife blade. Open the faucet just enough to get a very thin, but smooth and perfectly continuous stream of water; hold the point of a knife in the stream, well below the faucet, and note how the stream is broken, not only below, but for several inches above the knife.

The formula of Francis, and also that of Cippoletti, which is derived directly from it, are therefore admittedly unsuited for the computation of the discharge of weirs with end contractions when the head on the weir is greater than about one-third of the crest.

The authors, however, have recorded a comparison of their results with the results of computations by the Francis and Cippoletti formulas without regard for or comment on this limitation, although the maximum head of each separate series of their observations lies far above this limit.

TABLE 21.

	Length of weir, in feet.	Maximum head on weir, in feet.	Ratio of maximum head to length.
Cippoletti weir	0.5	0.95	1.89
	1.0	1.98	1.98
	2.0	1.99	0.99
	3.0	2.41	0.80
Rectangular weir	0.5	1.00	2.00
	1.0	1.34	1.34
	2.0	1.57	0.79
	3.0	2.06	0.69
Safe limiting ratio, as stated by Francis			0.33

An examination of the data of Francis, Fteley and Stearns, and Flinn and Dyer,* who experimented on the Cippoletti weir, shows that they all keep substantially within this approximate limit.

It is not surprising, therefore, that computations based on the Francis and Cippoletti formulas do not check the observed weir discharges. There are few or no precise data regarding the effect of end contractions on the discharge, when the weir is so short that the influ-

* *Transactions*, Am. Soc. C. E. Vol. XXXII, p. 9.

Mr. Longley. ences of the two end contractions overlap. A good idea of this effect may be obtained, however, from an analysis of the authors' data, on the assumption that their short weirs approximated the conditions of rectangular orifices.

Merriman gives the following formula for the rectangular orifice:

$$q = 8.02\ cbd\sqrt{h}$$

in which c is the coefficient of discharge,
b is the width,
d is the depth,
and h is the head on the center of the orifice.

Certain experiments by both Francis and Fteley and Stearns give the ratio of the depth of flow measured directly over the edge of a weir, to the depth measured above the origin of the surface curve, as approximately 0.86, and the depth of the orifice, therefore, may be taken as 0.86 of the observed head.

From this, for example, compute a few of the quantities for the 12-in. rectangular weir. An examination of Fanning's tables shows that the coefficient of discharge for the conditions assumed does not vary much from 0.61.

TABLE 22.

Number of run.	Average gauge height, in feet = h^l.	Assumed depth of orifice, $D = 0.86\,h^l$.	C.	Head on center of orifice, $h = h^l - \frac{d}{2}$.	Quantity, in Cubic Feet per Second.	
					By orifice formula.	By measurement.
1........	1.338	1.150	0.61	0.763	4.91	4.780
20........	1.233	1.060	0.61	0.703	4.34	4.292
3........	1.205	1.037	0.61	0.687	4.20	4.177
4........	1.130	0.972	0.61	0.644	3.81	3.757
2........	1.126	0.968	0.61	0.642	3.79	3.743
5........	1.044	0.898	0.61	0.595	3.39	3.332
6........	0.982	0.845	0.61	0.559	3.09	3.025
7........	0.909	0.782	0.61	0.518	2.75	2.695

Obviously, this computation comes a great deal closer to the measured discharge than does the Francis formula so far outside of its recognized limiting conditions.

The formulas the authors have deduced, and the rating curves they have prepared, are of value in computing the discharge of weirs identical with those used in the experiments; but the very diversity of coefficients and exponents which they have set forth in their twenty-one formulas, emphasizes the impossibility of their general application.

The points which are important to keep in mind are that the exhaustive work of Francis on weir measurement was corroborated in a substantial degree by the studies of Fteley and Stearns, and later

by the even more extensive researches of Bazin; that the formulas deduced by them have certain recognized limitations, and that, having proper regard for these limitations, the reliability of the formulas cannot be questioned. Mr. Longley.

W. G. Steward, Esq., and J. S. Longwell, Jun. Am. Soc. C. E. (by letter).—In his discussion Mr. Pierce brings out the point that the results of his experiments agree with those of the writers in that the actual discharge is greater than that given by the Francis formula, but that the velocity-area results show a smaller deviation than the volumetric tests. It should be remembered that Mr. Pierce's experiments were made on very large weirs, and that the departure of the actual discharge from the formula discharge occurs at gauge heights within the limits of accuracy, as generally taken, for the formulas, that is, for depths on the weir of less than one-third of the crest length. The results presented by the writers agree closely with the formulas for gauge heights above the limits of the formula in some cases, and practically to the limits in all cases. The percentages of difference between the writers' results and the formula at gauge heights equal to one-third of the length of the crest are shown in Table 23. Messrs. Steward and Longwell.

TABLE 23.

Size.	Percentage that the Actual Discharge is in Excess of the Formula at One-third of the Crest Length.	
	Cippoletti weirs.	Rectangular weirs.
6 in.	0	2.75
1 ft.	0	2.03
2 ft.	0.95	2.64
3 ft.	1.98	4.40

It will be noted that these differences are far below those given by Mr. Pierce for points of lower proportional gauge heights.

In the tabulation of the results of the writers' experiments, the discharge curves of the Francis formula and the Cippoletti formula have been used for a comparison of results. No attempt was made to show any discrepancy in these formulas; they were used for making a comparison, up to the limits of the formulas, and to show that, for gauge heights of more than one-third of the length of crest, the formula, as stated by Francis, does not apply. It is quite a common belief that the formulas are correct to almost any depth on the weir, in spite of the statement of Francis to the contrary.

The accuracy of the formulas within the stated limits was brought out quite clearly by the discharge curves, proving that, as long as the depth of water is less than one-third of the crest length, the formulas will give very accurate results.

Messrs. Steward and Longwell.

No attempt was made to develop any formula to apply for all depths, but the results of the actual tests were given and the resulting equations of the discharge curves tabulated. It is to be hoped that some general law of flow for all depths may be worked out by some one.

The following conclusions and formulas are presented for consideration. They are based on:

(*a*) The series of weir experiments conducted by the writers on the Boise Project, Idaho, in 1911.

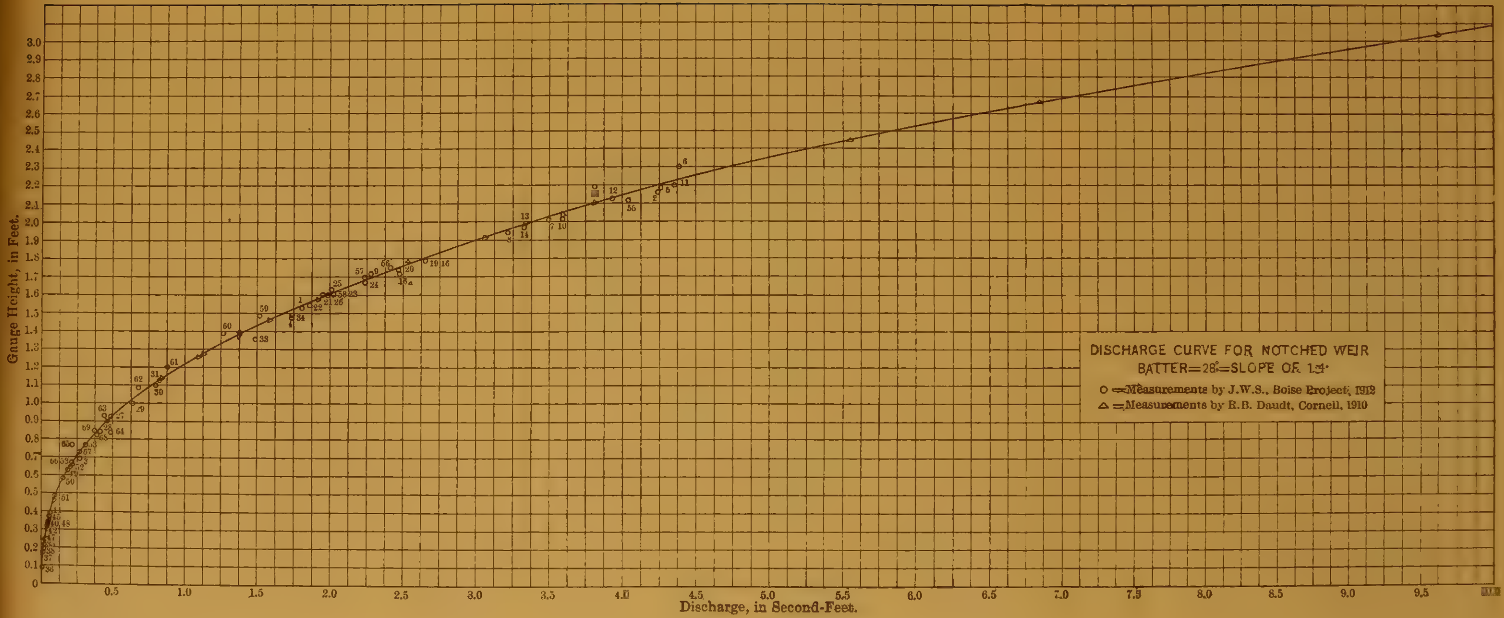
(*b*) The experiments on notched weirs conducted by Mr. J. W. Strohecker, on the Boise Project, in 1912. (See Plate LXXVIII and Table 24.)

(*c*) A series of experiments on notched weirs conducted by Ralph B. Daudt, Assoc. M. Am. Soc. C. E. (See *The Cornell Civil Engineer,* March, 1912; see also Plate LXXVIII and Table 24.

(*d*) A series of experiments on rectangular weirs conducted by Messrs. H. W. Maynard and J. P. Hurley. (See *The Cornell Civil Engineer,* April, 1912.) For a copy of the original notes on this series of experiments the writers are indebted to Mr. Paul Macy, Editor-in-Chief, *The Cornell Civil Engineer.*

TABLE 24.—Gauge Heights and Discharges in Experiments Conducted on Boise Project in 1912 by J. W. Strohecker on a Notched Weir; also Gauge Heights and Discharges in Experiments Conducted at Cornell University by R. B. Daudt, Assoc. M. Am. Soc. C. E., in 1910.

Experiments on Boise Project in 1912.												Cornell Experiments.	
No. of run.	Gauge.	Discharge, in second-feet.	No. of run.	Gauge.	Discharge, in second-feet.	No. of run.	Gauge.	Discharge, in second-feet.	No. of run.	Gauge.	Discharge, in second-feet.	Gauge.	Discharge, in second-feet.
36	0.094	0.002	66	0.666	0.224	33	1.36	1.382	19	1.79	2.672	0.4775	0.093
37	0.179	0.005	53	0.677	0.224	60	1.39	1.280	16	1.79	2.672	0.6619	0.214
38	0.195	0.009	3	0.69	0.268	4	1.48	1.734	8	1.945	3.236	0.9025	0.470
35	0.203	0.010	67	0.730	0.265	34	1.485	1.734	14	1.98	3.360	1.142	0.846
40	0.216	0.011	65	0.77	0.208	59	1.49	1.580	13	1.99	3.390	1.259	1.076
39	0.219	0.010	53	0.776	0.309	1	1.535	1.814	7	2.015	3.492	1.272	1.10
47	0.245	0.015	68	0.829	0.372	22	1.55	1.896	10	2.114	3.692	1.377	1.346
42	0.312	0.030	28	0.83	0.392	21	1.592	1.952	55	2.12	4.036	1.3875	1.349
43	0.318	0.034	64	0.84	0.492	26	1.595	1.980	12	2.135	3.936	1.4575	1.549
41	0.333	0.038	69	0.848	0.376	58	1.60	1.896	2	2.160	4.176	1.5855	1.89
48	0.350	0.041	27	0.921	0.492	23	1.608	2.066	18	2.169	4.230	1.7845	2.523
46	0.354	0.045	63	0.93	0.424	25	1.628	2.064	5	2.182	4.248	1.9179	3.087
45	0.38	0.049	29	0.996	0.638	24	1.674	2.236	11	2.185	4.282	2.0357	3.588
44	0.396	0.057	62	1.09	0.676	57	1.70	2.236	15	2.19	3.826	2.1045	3.803
51	0.479	0.094	30	1.094	0.794	9	1.713	2.352	6	2.301	4.392	2.4495	5.56
50	0.578	0.148	31	1.13	0.836	16a	1.72	2.412	....	......	......	2.6645	6.85
49	0.63	0.185	61	1.20	0.878	56	1.745	2.392	....	......	......	3.0375	9.632
52	0.650	0.204	32	1.22	1.480	20	1.748	2.472	....	......	......	......	......


DISCHARGE CURVE FOR NOTCHED WEIR
BATTER=28°=SLOPE OF 1:4
○ =Measurements by J.W.S., Boise Project, 1912
△ =Measurements by R.B. Daudt, Cornell, 1910
Gauge Height, in Feet.
Discharge, in Second-Feet.
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5

Messrs. Steward and Longwell.

TABLE 25.—COMPUTED FROM CORNELL EXPERIMENTS ON RECTANGULAR WEIRS, AND U. S. RECLAMATION SERVICE EXPERIMENTS ON NOTCHED WEIRS. THE TABLES GIVE THE DISCHARGE OF RECTANGULAR WEIRS, THE DISCHARGE OF 28° NOTCHED WEIRS, AND THE DISCHARGE OF THE TWO COMBINED, WHICH IS EQUAL TO THE DISCHARGE OF A CIPPOLETTI WEIR, AS SHOWN ON PLATE LXXIX.

Head.	Rectangular weir.	28° Notch.	Cippoletti weir.	Head.	Rectangular weir.	28° Notch.	Cippoletti weir.
3-INCH CREST.				1-FOOT CREST.			
0.25	0.10	0.02	0.12	0.31	0.48	0.03	0.51
0.45	0.23	0.08	0.31	0.75	1.93	0.29	2.22
0.94	0.74	0.52	1.26	0.985	2.97	0.59	3.56
1.46	1.41	1.44	2.85	1.19	4.01	0.94	4.95
1.88	2.08	2.95	5.03	1.39	5.06	1.38	6.44
2.29	2.88	4.70	7.58	1.66	6.74	2.16	8.90
2.705	3.76	7.73	11.49	1.91	8.36	3.07	11.43
3.08	4.54	9.43	13.97	2.05	9.35	3.55	12.90
......	....	....	.....	2.29	11.19	4.70	15.89
......	....	....	.....	2.51	12.70	5.95	18.65
......	....	....	.....	2.70	14.90	7.20	22.11
......	....	....	.....	2.76	15.44	7.60	23.04
......	....	....	.....	2.97	16.18	9.1	25.28
6-INCH CREST.				2-FOOT CREST.			
0.255	0.185	0.02	0.205	0.17	0.045	.....	0.04
0.58	0.66	0.17	0.83	0.55	2.41	0.135	2.54
0.93	1.39	0.51	1.90	0.86	4.80	0.42	5.22
1.34	2.50	1.26	3.76	1.27	8.91	1.09	10.00
1.61	3.30	2.00	5.30	1.63	12.85	2.07	14.92
1.89	4.21	2.99	7.20	2.12	19.11	3.85	22.96
2.13	5.09	3.90	8.99	1.91	16.45	2.97	19.42
2.40	6.18	5.30	11.48	2.29	21.74	4.70	26.44
2.65	7.07	7.20	14.27	2.46	23.90	5.60	29.50
2.87	8.32	8.35	16.67	2.64	26.87	6.80	33.67
3.05	8.73	9.70	18.43	2.73	28.67	7.40	36.07
.....	.....	....	.....	2.81	30.16	8.00	38.16
3-FOOT CREST.				4-FOOT CREST.			
0.145	0.51	....	0.51	0.27	1.84	0.02	0.186
0.402	2.49	0.06	2.55	0.425	3.52	0.07	3.59
0.730	5.72	0.27	5.99	0.625	6.27	0.19	6.46
1.08	10.44	0.75	11.19	0.92	7.17	0.50	7.67
1.34	14.72	1.26	15.98	1.11	14.67	0.80	15.47
1.52	17.45	1.74	19.19	1.31	18.79	1.20	19.99
1.67	20.28	2.20	22.48	1.47	21.79	1.59	23.38
1.84	23.43	2.72	26.15	1.63	25.80	2.06	27.86
1.95	25.98	3.21	29.19	1.82	31.02	2.72	33.74
2.10	28.18	3.88	32.06	1.905	33.02	3.05	36.07
2.29	31.93	4.90	36.83	2.035	36.11	3.58	39.69
2.41	34.63	5.60	40.23	2.22	41.72	4.50	46.22

CONCLUSIONS.

1.—The discharge of a sharp-crested, contracted, rectangular weir, with any given base and gauge height, added to the discharge of a 28° notched weir, with the same gauge height, gives a discharge equal to

Messrs. Steward and Longwell. that of a Cippoletti weir with the same base and gauge height. This is shown on Plate LXXIX where the combined discharge of a notched weir and rectangular weirs for various lengths of base are plotted, together with the discharges of Cippoletti weirs of equal bases.

2.—The relation of discharges of weirs of similar shapes, within the limits of experiments conducted, is the $\frac{5}{2}$ power of the proportion of bases at the same proportional gauge heights.

Formulas.

Let Q_1 = Discharge of a calibrated weir at head, h_1;
Q_2 = Discharge of another weir at head, h_2;
b_1 = Length of crest of calibrated weir;
b_2 = Length of crest of another weir the discharge of which is required;
h_1 = Head on calibrated weir;
h_2 = Head on weir having a base = b_2.

This head is taken so that

$$h_2 = \frac{b_2}{b_1} \times h_1 \text{; that is, } b_1 : h_1 :: b_2 : h_2 \text{, as shown by Fig. 7.}$$

Then Q_1 (at h_1) $\times \left(\frac{b_2}{b_1}\right)^{\frac{5}{2}} = Q_2$ (at h_2) in which $\left(\frac{b_2}{b_1}\right)^{\frac{5}{2}}$ is a constant.

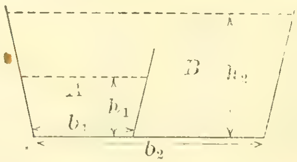


Fig. 7.

Which is derived as follows:

$$Q = cbh^{\frac{3}{2}}\text{, the theoretical formula for discharge of weirs}\ldots\ldots(1)$$

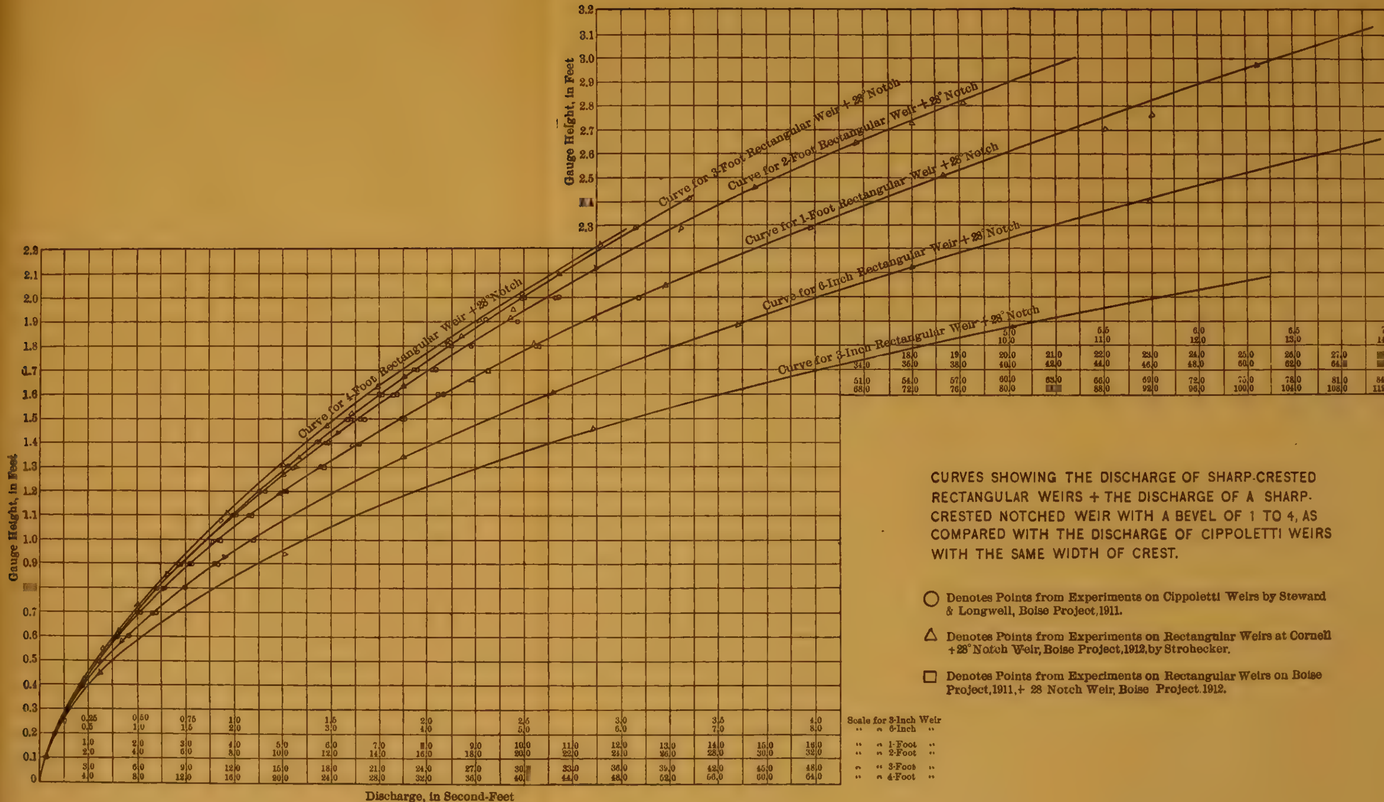
$$Q_1 = ch_1\,(h_1)^{\frac{3}{2}}\text{, the discharge of weir } A \text{ at } h_1 \text{ (at gauge height).}(2)$$

$$Q_2 = ch_2\,(h_2)^{\frac{3}{2}}\text{, the discharge of weir } B \text{ at } h_2 \text{ (gauge height as specified above)}\ldots\ldots(3)$$

$$\text{As assumed, } h_2 = \frac{b_2}{b_1} \times h_1 \ldots\ldots(4)$$

$$Q_2 = cb_2\,\frac{b_2}{b_1}\,h_1^{\frac{3}{2}}.\text{ Substituting in Equation 3 the value for } h_2 \text{ in Equation 4}\ldots\ldots(5)$$

$$Q_1 \times cb_2\left(\frac{b_2}{b_1}\,h_1\right)^{\frac{3}{2}} = Q_2 \times cb_1\,(h_1)^{\frac{3}{2}}\text{, multiplying Equations 2 and 5}\ldots\ldots(6)$$



CURVES SHOWING THE DISCHARGE OF SHARP-CRESTED RECTANGULAR WEIRS + THE DISCHARGE OF A SHARP-CRESTED NOTCHED WEIR WITH A BEVEL OF 1 TO 4, AS COMPARED WITH THE DISCHARGE OF CIPPOLETTI WEIRS WITH THE SAME WIDTH OF CREST.

Messrs. Steward and Longwell.

$$Q_1 \times \frac{b_2 \times \left(\frac{b_2}{b_1}\right)^{\frac{3}{2}}}{b_1} = Q_2.$$ Dividing by $cb_1 (h_1)^{\frac{3}{2}}$ and eliminating c and h_1..(7)

$$Q_1 \times \left(\frac{b_2}{b_1}\right)^{\frac{5}{2}} = Q_2 \quad \ldots\ldots\ldots\ldots\ldots (8)$$

(Conditions being specified above.)

Therefore, having the correct calibration of a weir with a given base and to any given height, the discharge of a weir of similar shape and with any desired length of base may be computed to a gauge height equal to the proportional lengths of the bases, provided the proportional shapes of forebay, crest, etc., are kept. This formula gives results well within the accuracy of the experiments conducted.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

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SOME EXPERIMENTS WITH MORTARS AND CONCRETES MIXED WITH ASPHALTIC OILS.

Discussion.*

By Arthur Taylor, Esq.†

Arthur Taylor, Esq. (by letter).—It is very pleasing to note that Mr. Page has been able to supply some additional data on his oil-mixed concrete investigation; primarily, because it undoubtedly furnishes the incentive for the Profession to enter further into this comparatively new field of concrete experimentation. Mr. Taylor.

It has been the desire of the writers, since their inextensive tests were undertaken, that they be instrumental in creating an interest in the investigation of this possibly economical means of water-proofing mortars and concrete, and they now believe that, due to Mr. Page's discussion, their hopes will be realized to some extent.

At the outset, the writers were quite confident that Mr. Page had demonstrated an economical and practical means of water-proofing mortars and concrete by the admixture of a mineral oil with wet mortars and concrete. In this belief, it was expected that they would be able to verify some of his conclusions and enlarge on the scope by the use of Western (asphaltic base) oils.

Somewhat negative results were first observed when the strength of the 7-day tensile specimens fell off with the "oil-mixes" to a greater relative degree than in Mr. Page's tests. In no case did the strength of the oil-mixed briquettes approach that of the plain mortar; nor did the strength of the oil-mixed specimens reach 80% of that of the no-oil specimens in the 28-day tests. Again, with the permeability test, the first specimens were watched to see the effect of the oil, and

* Continued from May, 1913, *Proceedings*.

† Author's closure.

Mr. Taylor. it was observed with regret that the oil-mixed specimens were more permeable than the plain ones, for it was hoped that results similar to Mr. Page's would be obtained.

Regarding the absorption tests, the noticeably slight absorption may be accounted for by the fact that the specimens were the broken halves of briquettes, undoubtedly poor examples from which to show normal absorption, but reasonable indicators of relative absorption of the various oil-mixed mortars. It was the practice of the writers to mix the mortars with exceptional thoroughness, and to pack the moulds quite vigorously, so that, without doubt, the latent voids were greatly reduced. This naturally brought about low absorption.

All specimens were taken out of the water at the same time, wiped, "baked" in an open gas oven at 160° Fahr., weighed, and again placed in water. At the end of the 24 and 72-hour periods the water was wiped off and the specimens were again weighed.

In the permeability test, though the age of the specimens was not great, the results of the plain concretes and the various oil-mixed ones, with relation to each other, should be quite correct. It is likely that the oil ingredient retards the time required for the concrete to reach its normal state, or permanent set; however, the writers cannot help but believe that the results of long-time tests would follow lines similar to those at 28 and 35 days, but probably with less divergence between the no-oil and oil-mixed specimens. By an oversight, the age of the 4-day test was omitted. These tests were begun on the thirty-fifth day.

The writers wish to make clear that the reporting of their tests was no flaunting declaration that oil as an incorporated ingredient in concrete is not an aid to its water-proofing qualities. It would be lamentable, indeed, if experimenters lacked the courage to make public their findings, merely because they did not agree with those of others. Believing in this principle, they offered their conclusions.

Though Mr. Page does not claim that oil adds to the strength, nor does the extra manipulation required to incorporate the oil (for it is not so shown in his compressive tests), yet the writers fail to comprehend why so many of Mr. Page's oil specimens have shown greater strength than the plain mortars. They have been inclined to believe that the "personal equation" is a factor in the results of new-field experimental work of this nature, regardless of how conscientiously it is carried on, and they dare say that it is likely that a repetition of many of these tests, where equative handling is paramount, would show appreciable reversals.

To some extent, the applicability of the colloidal theory does not seem futile. Considering oil the colloid, "that amorphous part of 'clays' which envelops the crystalline constituent, * * * when it is in excess, the clay is most plastic, and when it is dry, it is the less

permeable and less absorptive." This, however, is not in perfect analogy to cement, where a mechanical-chemical change takes place; therefore, can we impose the colloidal theory here? Mr. Taylor.

Again, it is plausible to believe that the oils of different character account to some extent for the variation in the results obtained from the experiments by Mr. Page and those by the writers.

J. B. Lippincott, M. Am. Soc. C. E., reported* that the tensile tests in the laboratory of the Los Angeles Aqueduct showed lack of uniformity, and were not considered to be encouraging for the use of California oils with concrete. These tests, however, were for tensile strength only, and no comment on any others was made.

When we consider the extent to which oil-mixed mortars and concretes has been investigated, it is only infinitesimal compared with what has been done with plain mortars and concretes. How many dozens of men have brought to light new and diverse results in their studies, but every result showing the investigators new light, and enticing them to experiment further. Therefore, this should encourage men to undertake more detailed study. Whether or not the writers' work led to the correct conclusion, they rest satisfied that they have created a stimulus for further investigation.

**Transactions*, Am. Soc. C. E., Vol. LXXIV, p. 283.

MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the record as here printed or correct any errors, should be forwarded to the Secretary prior to the final publication.

SAMUEL LISPENARD COOPER, M. Am. Soc. C. E.*

DIED MAY 8TH, 1913.

Samuel Lispenard Cooper was born in the City of New York on January 16th, 1858. His father, Samuel Hawes Cooper, was a nephew of Peter Cooper; his mother, Helen Sophia Lispenard was of French Huguenot descent. Mr. Cooper received his early education in the public schools of New York City and then studied at the College of the City of New York and at New York University. He was graduated from the latter institution in 1878 with the degree of Civil Engineer.

For the first five years of his professional career, Mr. Cooper was engaged on the surveys and preliminary work for the New Croton Aqueduct and Reservoirs, and was then placed in charge of the maintenance of the Old Croton Aqueduct, as Resident Engineer. In 1889 he entered the service of the Finance Department of the City of New York, as Supervising Engineer, and continued in this position for the next four years, gaining valuable experience in many directions. When the Department of Public Works of the City of Yonkers was organized, in 1893, Mr. Cooper was placed at its head as Commissioner, and continued in this position for 14 years until Yonkers became a second-class city, in 1908, when, under the reorganization that took place, he was appointed City Engineer, a position he filled until his death.

During 20 years of uninterrupted service with the City of Yonkers, first as Commissioner, and then as City Engineer, Mr. Cooper was responsible for the entire street system of the City. The City Pier and Recreation Pavilion were constructed according to his plans, and the City Hall Building was erected under his supervision. He also had much to do with making plans for the parks, and acted as Consulting Engineer to the Bronx Valley Sewer Commission and in connection with other enterprises.

In 1885, Mr. Cooper was married to Elizabeth Underhill, daughter of the Rev. George H. Goodsell, D.D., and niece of Bishop Daniel A. Goodsell, of the Methodist Episcopal Church, who with three children, Samuel G. Cooper, of Portland, Ore., Mrs. Raymond C. Rose, and Mary L. Cooper, survive him.

Mr. Cooper was an engineer of high ability, a man of sterling character and of indefatigable industry. Performing his duties with

* Memoir prepared by Edward Wegmann, M. Am. Soc. C. E.

absolute honesty, he could not avoid making enemies, but he won the esteem of all good citizens.

During the last two years of his life Mr. Cooper suffered from an incurable disease. He bore this misfortune with great fortitude, and attended faithfully to his official duties to the last, even when scarcely able to leave his home.

On May 8th, 1913, he was relieved from his suffering. His funeral was attended by the Mayor, Aldermen, and other City officials, past and present, of Yonkers, and by a large number of citizens who showed by their presence the high esteem in which they held their former City Engineer.

Mr. Cooper was a member of the New York University Alumni Association, Delta Upsilon Fraternity, a Director of the Hollywood Inn, a member of the Nepperhan Lodge of Free Masons, Terrace City Chapter of Royal Arch Masons, of the Elks, of the City Club, and of the Central Methodist Episcopal Church of Yonkers.

Mr. Cooper was elected a Member of the American Society of Civil Engineers on February 6th, 1889.

GEORGE BLINN FRANCIS, M. Am. Soc. C. E.*

Died June 9th, 1913.

George Blinn Francis, the son of Blinn and Lucy (Hart) Francis, was born at West Hartford, Conn., on January 31st, 1857. He received his early education in the public schools of his native town and at the Hartford High School, from which he was graduated at the age of 17.

On April 6th, 1874, he entered the employ of the Providence, R. I., Water-Works, as a student, and served for a period of three years in the Engineering Corps, during the construction of the Pettaconset Pumping Station. In March, 1877, he was transferred to the City Engineer's Department, which had just been consolidated with the Water-Works, where he served for the next 4½ years as Assistant Engineer, being assigned to the corps in charge of the "Brook Street District" improvements, and, on the completion of that work, to the Water Department.

In 1881 he joined the Engineering Department of the New York, West Shore and Buffalo Railroad and was assigned to the Ulster Division, in charge of a Hydrographic Corps between Fort Montgomery—at the southern entrance to the Highlands—and Poughkeepsie; later, he was made Assistant Engineer in charge of 4 miles of construction on this Division.

* Memoir prepared by John F. Wallace, Past-President, Am. Soc. C. E., and John W. Ellis, M. Am. Soc. C. E.

Early in 1883 Mr. Francis went to the Pacific Coast with a party selected to make surveys for a relocation of the Oregon Railway and Navigation Company's line between Portland and The Dalles, through the Cascade Mountains. In the spring of that year he was transferred to Portland as Assistant Engineer in charge of the construction of a large freight terminal, for the Northern Pacific Terminal Company, on the Willamette River, opposite Portland, including the construction of the car-ferry inclines, in connection with the transfer of passengers, for cars across the river, which were to be built in thirty days in order to be in readiness for the transfer of the famous "Gold Spike" party over the Northern Pacific Railway, in September, 1883.

On the completion of this work he returned East and for the next two years was employed on general railroad work—design, construction, and maintenance—including the preparation of plans for harbor works under the direction of the late James B. Eads, M. Am. Soc. C. E., in connection with his scheme for a ship railroad at Tehuantepec, and as Assistant Engineer, on the Hudson River Division (Weehawken to Albany), of the New York, West Shore and Buffalo Railroad, on maintenance of way.

In the fall of 1884, Mr. Francis resigned the latter position to accept that of Engineer of the Portland Construction Company, and as such had charge of the design of warehouses, docks, floating pile-driver, coal-pockets, bridges, floating dry-dock, etc. Subsequently, he became Resident Engineer on the construction of the Yakima Division of the Northern Pacific Railroad, returning East on the completion of this work. For the next three years he served in various positions on general railroad work, both design and construction, as follows: In the Engineer Corps on the Blue Mountain and Kittatinny Mountain Tunnels, on the South Pennsylvania Railroad, at Roxbury, Pa.; with the New Jersey Junction Railway, on field location from Weehawken to Bayonne, afterward having charge of the location and construction through Jersey City; and as Division Engineer on general railroad work on the Western Division of the New York Central and Hudson River Railroad, with headquarters at Rochester, N. Y.

On May 1st, 1887, he returned to Providence, R. I., as Principal Assistant Engineer of the New York, Providence and Boston Railroad, remaining in that position until March, 1892, when he was appointed Resident Engineer of the New York, Providence and Boston and Old Colony Railroad Terminal Company (subsequently controlled through lease by the New York, New Haven and Hartford Railroad Company), designing and constructing the Providence Terminal.

On July 1st, 1896, he became Resident and Acting Chief Engineer of the Boston Terminal Company, designing and constructing the South Terminal Station, in Boston, one of the largest passenger terminals in the world. With such care, foresight, and skill were the de-

tails of this intricate problem worked out that no important change has ever been made in the layout. The study and experience derived from the successful solution of these two important engineering works led Mr. Francis to specialize in this branch of the Profession, in which field he was recognized subsequently as a leading authority.

In the spring of 1899 he designed and supervised the construction of the foundations of the Kingsbridge Power Station of the Third Avenue Railroad, in New York City.

On the completion of the Boston Terminal, he became Chief Engineer of the Providence Street Railway System, and from February, 1900, to June, 1902, served during a very active period of construction and reconstruction of the Company's urban and interurban lines, building a new generating station, repair shops, car barns, etc.

Mr. Francis resigned to accept a position as head of the Civil Engineering Department of Westinghouse, Church, Kerr and Company, which Company had been retained as Engineers in connection with the new Pennsylvania Terminal in Manhattan, and, during the next eight years, the important civil engineering features of this work were under his supervision.

Some other terminal problems which received his attention are: The proposed Union Station at Toronto, Ontario; the proposed passenger and freight terminal, at Chicago, for the Chicago and Western Indiana Railroad; the Winnipeg Terminal, Grand Trunk Pacific Railway; Vancouver, B. C., Terminal, Canadian Pacific Railway; the proposed freight terminal, Canadian Pacific Railway, at Toronto; the proposed passenger terminal for the City of Buffalo; the rearrangement of the track layout, St. Louis Terminal; and many smaller terminals, both for passengers and freight, in the United States and Canada. As a member of the Railroad Committee of the Merchants Association of New York City, he rendered valuable assistance in the preparation of its report on "The West Side Improvements," relating to railroad and terminal facilities. He thrice visited Europe for observation and study of the large terminals in England and on the Continent.

Some of the many engineering problems which engaged his attention during his connection with Westinghouse, Church, Kerr and Company, were as follows:

Supervision of the construction of two high-speed interurban electric roads, one in the Lackawanna Valley, between Scranton and Wilkes-Barre, Pa., and the other in the Ohio Valley between Beaver, Pa., and Steubenville, Ohio; general supervision of the reconnaissance, location, and plans for a proposed high-speed electric road between Paterson, N. J., and Times Square, New York City; a proposed electric road between Rochester and Syracuse, N. Y., and a proposed line between Baltimore, Frederick, and Hagerstown, Md.; Consulting Engi-

neer on hydro-electric development for the Atlanta Water and Electric Power Company; Consulting Engineer, Shut-off Dam, Charles River Basin; Consulting Engineer, deep foundations, Providence Journal Building; Consulting Engineer, East Side Easy Grade Street, Providence, R. I.; Associate Consulting Engineer with Gustav Lindenthal, M. Am. Soc. C. E., on reconstruction of Locust Point Pier for the Baltimore and Ohio Railroad, at Baltimore, Md.; Consulting Engineer, heavy reinforced concrete bridge, designed for Bush and Gunpowder River Bridges, Pennsylvania Railroad; and investigations and reports on various water-power and irrigation projects in the South and West.

Mr. Francis was a member of the Institution of Civil Engineers of Great Britain; the Boston Society of Civil Engineers; the Canadian Society of Civil Engineers; the New York Railroad Club; and the Boston Engineers' Club. He was very active in the affairs of the Boston Society of Civil Engineers, having been the first non-resident member to be honored with the Presidency, which office he filled from March 17th, 1910, to March 16th, 1911.

He was Past-Master of What Cheer Lodge No. 21; Member of the Providence Royal Arch Chapter No. 1; Providence Council No. 1, R. and S. M.; Calvary Commandery No. 13, K. T., and of Rhode Island Consistory, A. A. S. Rite, N. M. J.

He was a frequent contributor to the technical press and to the publications of various engineering societies. In 1906, with W. F. Dennis, M. Am. Soc. C. E., he was awarded the Thomas Fitch Rowland Prize by the Society, for the paper entitled "The Scranton Tunnel of the Lackawanna and Wyoming Valley Railroad."* Other papers contributed to the Society by Mr. Francis are: "The South Terminal Station, Boston, Mass.," "Electric Railways in the Ohio Valley between Steubenville, Ohio, and Vanport, Pennsylvania," and "The New York Tunnel Extension of the Pennsylvania Railroad. Certain Engineering Structures of the New York Terminal Area."†

He was awarded a gold medal at the Paris Universal Exposition in 1900, in connection with the exhibit of the Boston Terminal Company; and in 1906, he received the Honorary Degree of A. M. from Brown University.

Mr. Francis was a man of keen perception, retentive memory, and rare judgment. He was quick to grasp the essentials of a problem, and brought to its solution a trained mind and a wide and varied experience. His genial disposition, democratic spirit, and kindly courtesy won for him the unfailing loyalty, unfeigned affection, and unwavering devotion of all who ever worked for or with him. His death is keenly felt by a host of friends and business acquaintances.

* *Transactions*, Am. Soc. C. E., Vol. LVI, p. 219.

† Joint author with Joseph H. O'Brien, M. Am. Soc. C. E.

and is a distinct loss to the Profession which he loved, in which his life found its expression, and for which he zealously labored.

In April, 1882, Mr. Francis was married to Florence Louise Greene, of Providence, R. I., who, with one son, George B. Francis, Jr., survives him.

Mr. Francis was elected a Junior of the American Society of Civil Engineers on September 5th, 1883, and a Member on November 7th, 1888. He had also served for two years as a Member of the Nominating Committee.

HORACE EBENEZER HORTON, M. Am. Soc. C. E.*

DIED JULY 29TH, 1912.

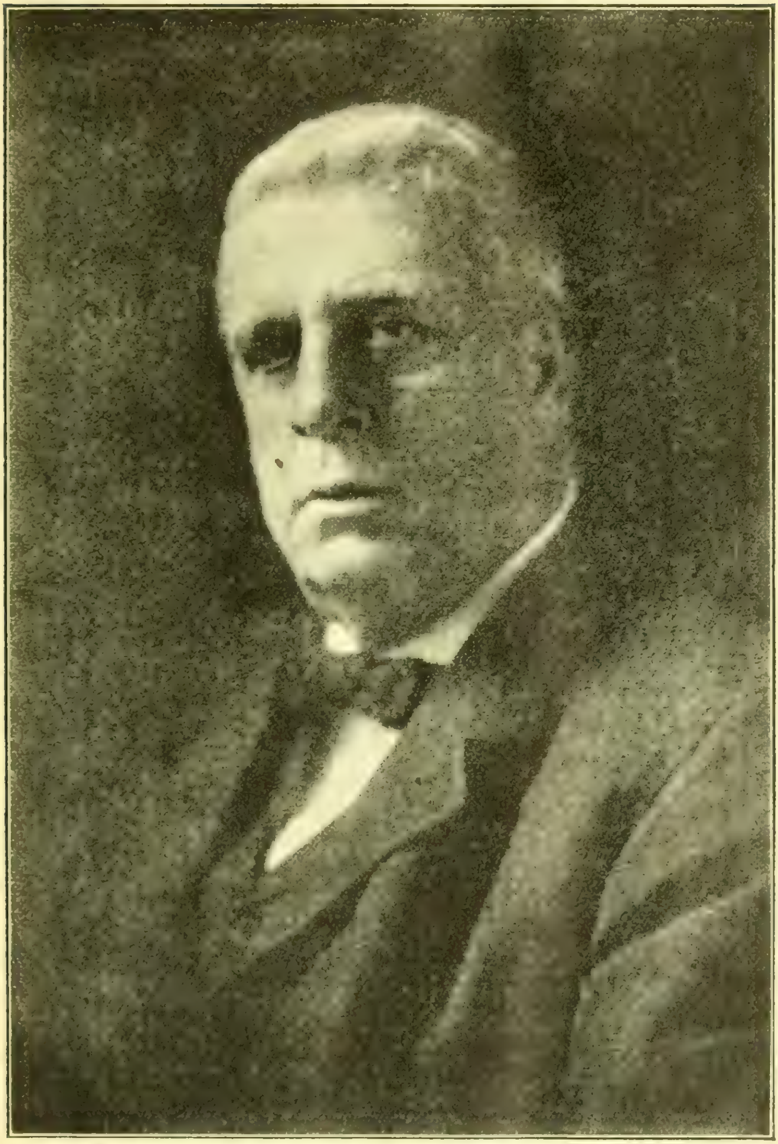
Horace Ebenezer Horton was born near Norway, Herkimer County, N. Y., on December 20th, 1843. Four years before the Civil War, when he was 13 years of age, his parents moved from Norway, N. Y., to Rochester, a small town in the southeastern part of Minnesota, at that time a frontier country. Here he was a pioneer, at an age susceptible to all the moving influences of a new country. Consideration of his after life leads to the belief that, as a western boy, he acquired those qualities of thoughtful planning, of initiative, and of self-reliance, for which he was distinguished in his manhood. With a fine mind, a splendid physique, and a natural fund of energy, this pioneer life was a good foundation for a working life characterized by ability, activity, and usefulness.

Mr. Horton's education in the schools was limited, as the schools were limited. At that time it may be said that engineering was not even a Profession, and engineering schools were almost unknown. At best, only an elementary engineering education could be offered in the schools of this country. Mr. Horton, doubtless, enjoyed such school training as was then obtainable. As a boy he attended school in Rochester, and later, for two years, at Fairfield Seminary in Herkimer County, N. Y., and was probably 19 or 20 years old at the completion of his course in that institution.

Considering the schools which he attended, and the proficiency which he displayed afterward in his Profession, it is fair to designate him as a self-educated man, and, like all true engineers, he continued to educate himself to the end of his life.

The timber bridge, at Oronoco, Minn., of 186 ft. span, 60 ft. above the water, was designed and built in 1866-67 by Mr. Horton, at the age of twenty-three. That a mere youth should combine the technical

* Memoir prepared by the following committee: Onward Bates, Past-President, Am Soc. C. E., Hugh L. Cooper, and Arthur J. Mason, Members, Am. Soc. C. E.



HORACE E. HORTON.

skill, the address to convince the authorities that the design was adequate, procure financial assistance, and have the business capacity to execute such a work, point out a man of very unusual powers and qualities.

One must remember that in 1866 Minnesota was a remote part of the world; that "Trautwine's Civil Engineer's Pocket-Book" was not published until six years later, and that the mass of technical literature we now have was not yet dreamt of.

The fact recalls Smiles' "Lives of the Engineers," those wonderful men, with little education, nearly all coming from the strip of north country across England, who gave us The Highway, The Canal, The Railroad, and The Extended Use of the Steam Engine in Modern Industry.

It is probably not a mere coincidence that the first Horton to land in America, in the seventeenth century, came also from Lancashire. One can readily believe that, running through the seven generations from the first Horton settled on Long Island, the constructive instinct persisted.

Horace E. Horton's father, a carpenter and builder, seventy years ago, in his wanderings between New York State and the far West, happened on some town in Ohio where a church had to be moved. The job frightened local talent, but Horton, Senior, undertook the work, succeeded, and, in his own words, "It paid handsome."

Here we have the Engineer's instinct strong in Horace E. Horton; a physical difficulty becomes a challenge or dare to overcome it.

Mr. Horton's career is of chief interest to us because he was one of the first group of engineers, fast disappearing, who grew up with the art; whose feeling for all kinds of material, structures, action, was the result of contact with them, and, therefore, became incorporated with his five senses, and instinctive.

A generation later, the Engineer's approach to knowledge in his work had become a literary one.

Horace E. Horton began his work with timber—the material of the country—and changed as the times changed. At his death his work was wholly in steel. He was always youthful in view point, always learning, never losing a sort of strong horse-sense.

Older members of the Society will recall his great impressive head, towering above the common run of men in any gathering.

Engineers are proud of the fact that the constructive quality seems ever to be accompanied with a certain robust force of character and probity. George Stephenson, the father of railways, a man who taught himself to read at the age of nineteen, was at home in the House of Lords, or any company, by reason of this mixture of sagacity, directness, and probity. Mr. Choate, in his address at the opening of the present Society House, traced these qualities to the fact that service

and performance are the sole tests of the Engineer's work—not an appeal to taste, as so largely in other professions. From Horace E. Horton there seemed at all times to emanate an atmosphere of these very qualities—sagacity, directness, and probity. To this fact is due his success in the world.

Mr. Cooper joined Mr. Horton's staff in boyhood, and remained in his service for many years. He describes one side of the man as follows:

"Those who knew Mr. Horton intimately, and as an employer, realized his possession of a mind of unusual endowments, and specially gifted in creative analysis and quick comprehension.

"The subject might be engineering, which he dearly loved as a Profession, or it might be politics, history, genealogy, the Bible, or civic life. The rapidity of his understanding and general comprehension sometimes naturally led to little expressions of impatience with those of lesser equipment.

"One of his striking qualities in his engineering practice was his universal refusal in middle life to accept anything he had previously designed as a standard for the future. Every new contract for a bridge, and they were many, required an entirely new set of drawings to bring out new ideas of main and detailed designs, and in this sort of work he seemed to find great pleasure. The fact that in his later life he originated and perfected to a fine success the water-tank with the hemispherical bottom, that is now so generally used, and that he maintained this design as a standard over a term of years, during which time he built some twenty-four hundred of these tanks, was a great surprise to those who knew him between 1890 and 1900.

"He was a man who possessed the courage of his convictions to a striking degree, and having once settled a problem, either as related to a design or a method of constructing it, his mind seemed absolutely at rest and to forget the element of responsibility as usually defined. Precedents in methods of construction were tossed aside whenever opportunity for original and bold treatment was presented, and his really interested originality always came through to a successful conclusion.

"In general, his manner toward his employees was given to brusqueness, but they soon came to understand that this attitude was a shield for a nature overly kind when properly appealed to.

"One of Mr. Horton's personal characteristics, that was very rare among men of his ability and always in evidence with him, was his great patience with a student employee who was trying to better his condition through special studies after hours and through special hard work during working hours. To such he was never known to deny all the time the student asked for, and it frequently resulted in the student getting more time given him than he in his unwisdom thought he needed. His pride in the advancement of his 'young men,' as he called them, never came to the attention of the student, except when stories of their progress were told by Mr. Horton to third parties.

"His notions of charity followed most strictly the biblical inhibition about giving. He gave generously and freely to the needy, but al-

Timber Bridge, Oronoco, Minn., 1866-67.

ways in a manner that successfully precluded the possibility of even minute public knowledge. During his residence in Chicago he listened to a very strong appeal from the pulpit for funds with which to purchase a pipe organ for the church. A day or two afterward he met the pastor and told him that he would give a certain sum toward the purchase of the organ, which amount happened to be 75% of the total cost, provided he would never breathe a word about the contribution to a soul. The pastor took the subscription, gave the exacted promise, and then went to another member of Mr. Horton's immediate family, stated that he had secured 75% of the necessary amount, asked for further aid, received 15% of the necessary amount, and gave the same promise about secrecy. The pastor knew from previous experience how to proceed, and was a skilled solicitor; at the first opportunity he appealed to yet another member of Mr. Horton's family, and obtained the remaining 10% for the organ, on the execution of the same promise regarding secrecy. It is believed that the family do not to this day know how that church got that organ, but the truthfulness of this story is vouched for, and is only related to evidence a trait of character beautiful and none too common.

"The possessor of great physical and mental strength, it is difficult to realize that he could so quickly succumb, and his going away will long be foundation for sadness in the minds of those he befriended."

As a bridge builder, his contracts were obtained by competitive bids, usually on plans prepared under his direction. These plans were required to conform to specifications and meet the approval of the engineer representing the purchaser. The successful bridge contractor had to design a structure meeting all requirements, and be the lowest bidder, as well. Success depended on the skill of the designer in producing the most economical structure to manufacture and erect. It was the custom for bidders to assemble at the time and place set for letting the contract, and the occasion was one in which competitors met in a friendly rivalry, although sometimes it was not so friendly. Competition was very keen, and, if by any chance a bidder lost his opportunity to bid, he was rather the butt of the jokes of the other bidders than an object of sympathy with them.

Mr. Horton was always a generous rival. He would encourage competition instead of suppressing it. It seemed as if he entered into the spirit of the game, on the principle that "the more the merrier," and that, if he won, his success was greater with many than with few to bid against. An instance of this is related by Mr. Bates, on the occasion of the letting of the superstructure for the high bridge at St. Paul. The bridge contracting company which Bates represented had arranged that the bidder's bond required by the city should be furnished to him through a local bank in St. Paul. On the morning of the letting of the contract, and perhaps two hours before the bids were to be opened, he called at the bank with full assurance that the bond would be passed over the counter to him. To his surprise and dismay,

he was informed that some hitch, in the arrangement with the Philadelphia bank which was to guarantee the bond, prevented the St. Paul Bank from furnishing it. The decision was final, as it was impossible to make other arrangements in the limited time. Coming out of the bank, Bates paused on the steps of the building, reflecting on his position and wondering if anything could be done to save his bid. Just then Mr. Horton appeared, and, looking up, asked, "What is the matter? Why are you looking so sorrowful this morning?" He was informed of the dilemma of his competitor. Then Horton's fine instinct came to the rescue. He took Bates by the arm and said: "This will never do. We must get you a bond at once." Going to the nearest office building, they scanned the list of tenants, found the name of a lawyer and proceeded to his office. The lawyer was instructed to draw up the bond at once. Horton remarked: "The amount of this bond is so large that I cannot qualify for the whole of it myself, and we must get another bondsman." They proceeded from the building and on reaching the street, the first man who passed was seized by Horton and told that he must come in at once and sign Bates' bond, not even giving the newcomer an opportunity for argument. The matter was satisfactorily concluded. Bates' bid was considered, and when the decision on the bids was made known, the contract was Horton's as the lowest bidder.

Mr. Bates states that he never was so pleased at the success of a rival, and that a man who could show the spirit that Mr. Horton did under the conditions, was worth his lasting friendship.

Returning to Rochester, Minn., from his studies at Fairfield Academy, about twenty years of age, the next few years were devoted to whatever seemed to offer—farm work, surveying, railroad location—until we find him engaged on the Oronoco Bridge, described at the opening of this memoir.

With this as his starting-point, he was duly launched on his life work. For the following twenty-three years he had his headquarters at Rochester, and built up an extended business in the designing and erection of highway bridges throughout a considerable area of the Northwest. During this time he also developed some skill as an architect, designing a number of public buildings, as well as private residences.

A paper* entitled "Bridge Legislation," by Mr. Horton, is a delicious sample of the mixture of wit, clear-headedness, technical skill, and force of character of the man. Members will recall an occasion, years ago, when an effort was made to obtain acts of State Legislatures providing that highway bridges in the country should be under the supervision of some State officer or engineer, much as buildings are under the superintendent of buildings in cities.

**Journal*, Association of Engineering Societies, Vol. XI, p. 54 (February, 1892).

Mr. Horton believed that this movement implied a failure to understand and appreciate the very remarkable ingenuity, skill, energy, and economy which had been shown by the men building highway bridges in the West, with funds seeming to us now humorously insufficient, in places remote, and under circumstances of extraordinary variety and difficulty.

Mr. Horton states a case which we venture to insert as a clean-cut sample of his logic and astonishing economy of design and execution.

"A congressional township (six miles square) with an assessed valuation of $38,000, had a stream running through it requiring a 200-ft. bridge; at medium low water the stream could be forded, but with a rise of one foot it was dangerous.

"Within ten years preceding the building of the bridge, three people had been drowned (one each, on three separate occasions) in attempting to ford the stream.

"With all available funds, and all ability for contracting a debt, the township was able to apply $1,800 for this work. It seemed to be best to build the bridge in one span.

"The abutments cost $500. A 200-ft. span was built for $1,300 (with profit to the builder), which has served eight years, with every prospect of use for a long term of years in the future.

"The thought comes to me: What would the engineers of legislation have done with a case like this. Would they have insisted on this community continuing to take chances on the ford, or have taken themselves out of the way, and allowed a man, with knowledge of how to do it, to build a bridge?"

Again, he says in the same paper:

"Have the committee been careless in their statements or shall I (having built thousands of highway bridges, and never having occasion to apologize for a failure either in design or execution) thank God for his mercy (being myself incompetent) * * * that these works have developed into bridges instead of hetchels."

Like most strong men, sure of themselves, he loved a "scrap."

Up to 1889 he had conducted his business, as a bridge contractor, independently of any shop. He had begun in the days of timber bridges, had passed through the combination stage, and had seen the metal bridge become the universal one. In 1889, recognizing that he must either become a manufacturer or lose his identity in the business, he moved to Chicago, and in conjunction with others started the Chicago Bridge and Iron Company, of which he was the President and Manager until the destruction of the plant by fire in 1897. At that time Mr. Horton purchased all the outside stock in the company, rebuilt the plant, and operated it thereafter in his own name, as the Proprietor of the Chicago Bridge and Iron Works.

Mr. Horton's great ability was as an engineer and as a contractor, rather than as a manufacturer. The interminable detail work of the

latter annoyed him, and it was a great pleasure to him in later years to turn over much of this to his eldest son.

As an engineer, Mr. Horton was always progressive. When the combination of wood and iron became economical, he was prepared to use them to produce rational designs therewith. When the virtue of cantilever constructions for certain conditions was pointed out, he was ready to make use of them. A man of the most thorough commonsense, he utilized this in the design of his structures, which were proportioned to the service they were expected to give, rather than to some letter of a specification. At a time, twenty-five years ago, when communicating bridges were in demand by cities located on the banks of the Upper Mississippi River, where the conditions necessitated long and high structures, with only a very limited amount of money available, he designed and built bridges which were strictly adapted to their service and have continued all these years properly to take care of the business. They were very light, and relatively inexpensive, structures, but they showed the skill of the designer, and the adaptation of means to ends. There was no metal wasted; every pound was used to the best advantage.

Perhaps Mr. Horton was best known to many people through his improvements in elevated water-tank design and construction. In 1894 he brought out a design for a steel water-tank supported on steel columns, the tank having a hemispherical bottom, and the columns connecting directly to the sides of the tank. Of this, his son, George T. Horton, M. Am. Soc. C. E., writes:

"He brought out these two essential elements which made the steel tank commercial with not over a half hour's study. The more I think of this one thing, the more remarkable it seems."

Prior to this, though the steel tank on steel columns had been used quite extensively, its general adoption had been prevented by the expense incident to the method of construction. The tanks had generally been flat-bottomed, supported on the columns by heavy floor-beams and closely-spaced joists, though there had been some instances of tanks with conical bottoms, and also with segmental bottoms, both these forms necessitating materially more metal, as well as more expensive shop work, than did the full hemispherical bottom produced by Mr. Horton. The method he adopted, too, for dishing these bottom plates, was novel and inexpensive. The result of these improvements, as well as of the energy and skill with which the sale of the structures was promoted by him, has been the general adoption of this form of elevated tank, and examples thereof are to be found in all portions of America, and the world generally, many of which are the product of his shop.

Mr. Horton's skill and courage as a contractor fully equalled and perhaps surpassed his ability as an engineer. In his case, the engi-

neer and contractor were one. Being satisfied that a certain thing was feasible, he had the courage and skill, both as an engineer and as a contractor, to carry it out. If the state of the art did not provide the tools and facilities to suit him, he promptly devised them. He had a great deal of ingenuity, amounting to the true inventive instinct, and his shops contain many evidences thereof. So far as known, however, he never patented any improvement he made.

Mr. Cooper vouches for the following, which is worth telling as characteristic of the man, and goes to show that the same person may be at once shrewd and a money maker, and withal a generous man:

"Along about 1891 a strong competitor of Horton's was forced into the hands of a receiver. I happened to be in the office the next morning after the failure, and Horton, seeing the notice of the failure in the morning's paper, ordered me to bring him his check book, and he thereupon drew a check for $5,000 to the order of the President of that company and sent it to him with a brief note, stating that he undoubtedly needed a little household money and asked him to accept the check with his best compliments. As far as I know, and I think I am correctly advised, this check was never repaid, and was never expected to be repaid by Horton."

The foregoing incident seems to his biographers to be especially typical of the man, who, throughout his life, was large minded enough to act outside and above conventionality. He was probably influenced in this case, strange as it may seem, by the very reason that he was neither the same kind of a man nor an intimate friend.

Mr. Horton was married in 1871 to Miss Emma Babcock, of Waupun, Wis. She survives him, with their five children, George T. Horton, Mrs. K. Koessler, and Horace B. Horton, of Chicago; Mrs. R. H. Murray, and Hiram T. Horton, of Greenville, Pa.

He died at his home in Chicago on July 29th, 1912, aged 69, and was buried at Rochester, Minn.

Mr. Horton had a long list of friends who admired his personal qualities and who recognized his professional talent by electing him as President of the Western Society of Engineers, and as a Director of the American Society of Civil Engineers.

Mr. Horton contributed to the *Transactions* of this Society discussions on the following subjects: "The Halsted Street Lift Bridge," "Elevated Railroads," "Safe Stresses in Steel Columns," and "Tests of Large Steel Columns." He was the author of the following papers in the *Journal* of the Association of Engineering Societies: "Bridge Legislation" and "The Compressive Member." Mr. Horton's "Address," as President of the Western Society of Engineers may be found in the first volume of the *Journal* of that society, to which he also contributed discussions on: "Specifications for Steel Railroad Bridges," "Northern Pacific Standard Bridge Plans," "Specifications for Steel

Structures," "Modern Practice in Bridge Shop Work," and "Curious Lattice Trusses."

Each of these papers and discussions will be found interesting, even to the layman, from the ability shown to discuss the most complex questions, in simple language, and comparatively free from formulas.

Isham Randolph, M. Am. Soc. C. E., in a letter to the writers, but voices, we believe, the judgment of the Engineering fraternity:

"Often we come in contact with men of heroic stature, whose only claim to consideration is a physical appeal to the eye; from within the human effigy there comes forth to fellow-man nothing helpful, nothing to be admired.

"How different it was with Horace E. Horton. There was a man of commanding stature, manifestly of great physical strength, but with no faint suggestion of brute force. His noble head towered above his broad shoulders, and his whole appearance was but 'the outward and visible sign' of a great personality, dominated by a bigness of mind and of heart that made him both a leader and friend of his fellow-man, and won for him not alone the esteem, but the love of those with whom he came in contact in the varied relations of a life lived on a broad plan of usefulness.

"These are my epitomized thoughts of a man whom I admired and whose friendship I valued."

Horace E. Horton was elected a Member of the American Society of Civil Engineers on September 6th, 1882, and served as a Director during 1907-08-09.

CHARLES DE LA PLANE ATTERBURY, Assoc. M. Am. Soc. C. E.*

Died June 3d, 1912.

Charles De La Plane Atterbury was born at Howard City, Mich., on June 3d, 1878. His earlier years were spent in Utah, where he received instruction in private schools, and, for a short time, at the University of Utah.

He took up work as a telegraph operator at Murray, Utah, for the Rio Grande Western, and later was employed in the same capacity and as Agent on various roads and in various places in Oregon, Washington, and Idaho.

Mr. Atterbury began his technical education when he entered Leland Stanford, Jr., University, as a freshman in 1901. His sophomore year was spent at the University of Oregon, and his junior year at the Colorado School of Mines. Practical experience in mining engineering in Colorado was later found to be of considerable benefit to him in his chosen work. He again entered Stanford University as a senior in 1904, and it was here that the writer met and worked with him

*Memoir prepared by H. B. Langille, Esq.

in various courses during the year, learning all the while the many sterling and admirable qualities of a character best known only to those in close association with him.

Before graduation, in the spring of 1905, he passed the examination for Engineering Aid in the Reclamation Service, with such standing as to merit immediate appointment. He was assigned to duty on the irrigation project at Hazen, Nev., for a short time on office work; later, he had charge of a party in the field. His ambition was not satisfied with the slower chances for advancement in Government work, so he resigned to enter the employ of a large corporation engaged in Alaska railroad development. On leaving this service he returned to Tacoma, Wash., and entered the employ of the Oregon-Washington Railroad as Division Engineer on a branch road near Centralia, Wash. After the completion of the road, he opened an office in Centralia, making a specialty of mine surveys in the coal region there, his previous experience fitting him for success in that work.

In the spring of 1908 Mr. Atterbury was appointed Assistant City Engineer of Centralia under Mr. Bullard, then City Engineer, and, on the resignation of the latter, some months later, was appointed to fill the vacancy. Many substantial improvements were made in Centralia and the neighboring city, Chehalis, during his term of office as City Engineer, for the success of which he was in large measure responsible.

A change in the form of government and personnel of city officers induced Mr. Atterbury to resign in the spring of 1912, dispose of his home, and return to California. He immediately entered the employ of a large contracting firm in San Francisco, and was engaged in special construction, the requirements of which necessitated work in the tule bottom lands along the Sacramento River. During the excessively warm weather of 1912 his party suffered much from heat and lack of good water, Mr. Atterbury being much more affected than the others, due to his having come so recently from the cooler northern State. On the Friday preceding his death, which occurred on June 3d, 1912, he was partly overcome by the heat, but quickly recovered and made light of the occurrence. His wife, however, induced him to come to San Francisco for Saturday and Sunday, with the intention of giving up that work altogether. His characteristic conscientiousness and sense of duty to his employers' interests compelled him to return to the work, it being his intention to remain only Monday and Tuesday.

Work was prevented by the heat on Monday, but it was resumed on Tuesday, which, however, proved to be the hottest day of the year. In the tule rushes, which are 10 or 12 ft. high, the air does not move near the ground, hence is excessively moist and warm. The party started to return in the middle of the afternoon, two of the stronger

men being sent ahead for water. On their return, while cautiously making their way through the tules to avoid being seen, they were observed by the others, and, as is usual in such cases when help arrives, Mr. Atterbury succumbed and fell. Some water and much rough handling brought him to his feet again, but for a short time only, when he fell once more and died before he could be carried to the nearest shelter. Two others of the party were overcome also, but were revived.

This was another instance of that quality of devotion to duty so frequently found in the Engineering Profession, and so strongly manifested in Mr. Atterbury. His was a character at once lovable, quiet, and unassuming; he was devoted to his family, loyal to his friends, purposeful, resourceful, and with high ideals of personality and profession; a clean, manly man whose passing is a distinct loss to his Profession and to the community in which he lived.

In May, 1907, Mr. Atterbury was married to Miss Ida Small, whom he met while at Stanford, and who, with two children, survives him.

Mr. Atterbury was elected an Associate Member of the American Society of Civil Engineers on November 8th, 1909.

CHARLES HARRY TISDALE, Assoc. M. Am. Soc. C. E.*

Died April 30th, 1913.

Charles Harry Tisdale, the youngest child of Benjamin F. and Eliza H. Tisdale, was born in New Orleans, La., on May 30th, 1874, but after living there only a short time the family removed to the country just outside of Baton Rouge, La., where his early boyhood was passed. He attended the small country schools, but learned principally from his mother's tuition. The family afterward removed into the City of Baton Rouge, where he attended the public schools. He then entered Louisiana State University, from which he was graduated in 1895 with the degree of B. S.

His first work was to teach school at Brusle' Landing, West Baton Rouge Parish, La., where he met the young lady who afterward became his wife.

He taught school only one term, and then accepted a position under Col. George McC. Derby, M. Am. Soc. C. E., who then had charge of the Fourth Mississippi River District, with headquarters in New Orleans. Mr. Tisdale was in that office only a short time, being employed in the Drafting Department; afterward he went into the field as Inspector of levee construction.

* Memoir prepared by Robert R. Tisdale, Esq.

In 1902 he was transferred to the Mobile, Ala., District, where he worked in the Drafting Department for about a year. He was then sent into the field and served successively as Recorder, Inspector, and Junior Engineer, in connection with the building of locks and dams on the Alabama and Tombigbee Rivers, Ala.

In the early part of 1906, Col. H. C. Newcomer, who was then in charge of the Chattanooga, Tenn., District, sought a capable man to place in local charge of the projected lock and dam at Hales Bar on the Tennessee River. Mr. Tisdale was selected for the position, was appointed Junior Engineer on February 1st, 1906, and placed in charge of the work. He was there when ground was broken, and remained in charge until his death. There he had his greatest sorrow, his young wife being called away without a moment's warning. His only consolation seemed to be his work, in which he absorbed himself. He saw it growing toward completion after many difficulties had been overcome, and yet he was not spared to see it completed. He knew every inch of the construction and every man connected with it in any way. When finished it will be an enduring monument to him. As the mighty Tennessee rolls onward past the dam, between the mountains standing like sentinels over it, as the turbines whirl in the current and manufacture light and power for distant Chattanooga, they will bear witness to the faithfulness of the one who wrought so earnestly and yet did not live to see the completion of the great project.

Faithful to friends, loving toward his family, and zealous in the performance of his duty, he is mourned by many.

Charles Harry Tisdale was elected an Associate Member of the American Society of Civil Engineers on October 31st, 1911.

PAPERS IN THIS NUMBER

PAPERS AND DISCUSSIONS CURRENT IN PROCEEDINGS

PAPERS IN THIS NUMBER

PAPERS AND DISCUSSIONS CURRENT IN PROCEEDINGS

620.6

William P. Morse

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

VOL. XXXIX—No. 7

AMERICAN SOCIETY OF CIVIL ENGINEERS FOUNDED 1852

PRE... TO
N.
ENGINE... SOCIETY
WILLIAM P. MORSE

September, 1913

Published at the House of the Society, 220 West Fifty-seventh Street, New York, the Fourth Wednesday of each Month, except June and July.

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PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

(INSTITUTED 1852)

VOL. XXXIX—No. 7

SEPTEMBER, 1913

Edited by the Secretary, under the direction of the Committee on Publications.

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NEW YORK 1913

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On Steel Columns and Struts: Austin L. Bowman, Emil Gerber, Charles F. Loweth, Ralph Modjeski, Frank C. Osborn, George H. Pegram, Lewis D. Rights, George F. Swain, Emil Swensson, Joseph R. Worcester.

On Bituminous Materials for Road Construction: W. W. Crosby, A. W. Dean, H. K. Bishop, A. H. Blanchard.

On Valuation of Public Utilities: Frederic P. Stearns, H. M. Byllesby, Thomas H. Johnson, Leonard Metcalf, Alfred Noble, William G. Raymond, Jonathan P. Snow.

To Investigate Conditions of Employment of, and Compensation of, Civil Engineers: Alfred Noble, S. L. F. Deyo, Dugald C. Jackson, William V. Judson, George W. Tillson, C. F. Loweth, John A. Bensel.

To Codify Present Practice on the Bearing Value of Soils for Foundations, etc.: Robert A. Cummings, Edward C. Shankland, Edwin Duryea, Jr., James C. Meem, Walter J. Douglas, Samuel T. Wagner, Frank M. Kerr.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

House of the Society—220 West Fifty-seventh Street, New York.

Telephone Number....................5913 Columbus.
Cable Address...................."Ceas, New York."

Vol. XXXIX. SEPTEMBER, 1913. No. 7.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PROCEEDINGS

This Society is not responsible for any statement made or opinion expressed in its publications.

SOCIETY AFFAIRS

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MINUTES OF MEETINGS

OF THE SOCIETY

September 3d, 1913.—The meeting was called to order at 8.30 P. M.; Vice-President J. Waldo Smith in the chair; Charles Warren Hunt, Secretary; and present, also, 121 members and 15 guests.

The minutes of the meetings of May 21st, June 4th, and of the Annual Convention, were approved as printed in *Proceedings* for August, 1913.

A paper by A. M. Strong, Assoc. M. Am. Soc. C. E., entitled "The Storage of Flood Waters for Irrigation: A Study of the Supply Available from Southern California Streams," was presented by title and the Secretary read a communication on the subject from Charles H. Lee, Assoc. M. Am. Soc. C. E.

A paper by Charles W. Staniford, M. Am. Soc. C. E., entitled "Modern Pier Construction in New York Harbor," was presented by title, and communications on the subject, from Messrs. E. G. Walker, Edwin J. Beugler, and Harrison S. Taft, were read by the Secretary. The paper was discussed orally by Messrs. F. R. Harris, S. M. Purdy,

B. H. Wait, L. D. Cornish, F. Lavis, J. P. Snow, F. A. Snyder, R. T. Betts, T. B. Shertzer, and C. H. Stengel.

The Secretary announced the election of the following candidates on September 3d, 1913:

As Members

John William Craig, Baltimore, Md.
Arthur Crumpton, Port Hope, Ont., Canada
John Samuel Eastwood, San Francisco, Cal.
John Morrice Roger Fairbairn, Westmount, Que., Canada
Horace Williams King, Ann Arbor, Mich.
John Hancock Lance, Wilkes-Barre, Pa.
William Junius Lester, Pueblo, Colo.
Walter Huntley Mansfield, Troy, N. Y.
Harry Alonzo Noble, Berkeley, Cal.
Frank Louis Raschig, Cincinnati, Ohio
Edward Manly Royall, Jr., Charleston, S. C.
Robert Carlos Sattley, Chicago, Ill.
William Stanton Twining, New York City

As Associate Members

James Perrie Alvey, Jr., Chicago, Ill.
Bertrand Don Barker, Chicago, Ill.
Joseph L Burkholder, Parma, Idaho
Alfred John Cleary, San Francisco, Cal.
Frederick George Cross, Bassano, Alberta, Canada
Edwin Sanford Cullings, Albany, N. Y.
David Hesba Dugan, Chillicothe, Ill.
Conrad Francis Dykeman, Brooklyn, N. Y.
Gwynne Wallace Ellis, Kansas City, Mo.
Morris Cable Emanuel, Fort Smith, Ark.
Thomas Willard Espy, San Francisco, Cal.
Ozro Nowlin Floyd, Dayton, Ohio
Francis Eugene Freeland, Nashville, Tenn.
Ralph Lyman Harding, Manila, Philippine Islands
Floyd Sinnock Hewes, Winslow, Ariz.
Luther Romberger Hoffman, Detroit, Mich.
William Whitehead Hurlbut, Los Angeles, Cal.
Joseph Frederick Jackson, New Haven, Conn.
Lebrecht Julius Klug, Milwaukee, Wis.
Herman Charles Kuhl, Fort Shaw, Mont.
Lauritz Lauritzen, San Francisco, Cal.
Egbert Vanhorn Lawrence, New York City
George Thomas McClean, Fort Stevens, Ore.
George Earle McCurdy, Glen Ellyn, Ill.
Evan Search Martin, New York City

Charles Rea Moore, Perry, Wash.
Leroy Norman Reeve, Arrowrock, Idaho
Roy Karl Schlafly, Columbus, Ohio
John Joseph Henry Sharon, San Francisco, Cal.
Adolphus Gustavus Trost, El Paso, Tex.
Isaac Stanley Walker, Brooklyn, N. Y.
William Kemp Walker, Wichita, Kans.
Roscoe George Walter, Prairie du Sac, Wis.
Frank Edwin Washburn, Leavenworth, Kans.
David Loyall Farragut Watson, Los Angeles, Cal.
Wade Clarence West, Manila, Philippine Islands
Herbert Angell Whitney, San Diego, Cal.
James Wilson, Montchanin, Del.
Stanley Hubert Wright, Philadelphia, Pa.
Charles Wuest, Jr., Cincinnati, Ohio

As Juniors

Fred Drexel Bowlus, Pasadena, Cal.
Graham Bernard Bright, Blacksburg, Va.
John James Clark, St. Louis, Mo.
Alfred Henry Clarke, Portland, Ore.
Merton Clyde Collins, San Francisco, Cal.
Meyer Davis, Beaver Falls, Pa.
James Gordon Goodfellow, Lyttelton, New Zealand
Whitney Irwin Gregory, Louisville, Ky.
Alfred Sparks Hirzel, Wilmington, Del.
Henry Collins Hitt, Olympia, Wash.
Andrew Hall Holt, Burlington, Vt.
Frank Osborne Lee, Burlington, Vt.
Edwin Hall Marks, Washington, D. C.
William Floyd Way, Fresno, Cal.
Walter John Willis, New York City
Calvin Loughridge Wilson, Fort Worth, Tex.

The Secretary announced the transfer of the following candidates on September 3d, 1913:

From Associate Member to Member

Wallace Edward Belcher, New York City
Edward Fryling Black, New York City
Orrin Lawrence Brodie, New York City
John Augustus Bruce, Omaha, Nebr.
Walter Charnley, São Paulo, Brazil
Charles Edwin Collins, Philadelphia, Pa.
Clarence Goldsmith, Charlestown, Mass.
Verne LeRoy Havens, New York City

William Christian Hoad, Ann Arbor, Mich.
Adolph Judell, San Francisco, Cal.
Walter Burditt Leane, Santiago, Chili
Charles Tileston Leeds, Pasadena, Cal.
Frederick Ewbank Leefe, Florence, Ore.
Ira Welch McConnell, Boston, Mass.
Chester Leroy Post, Chicago, Ill.
John Charles Riedel, Brooklyn, N. Y.
Edward Farnum Rockwood, Boston, Mass.
Vernon Lyle Sullivan, Buenavista, Tex.
Leslie Abram Waterbury, Tucson, Ariz.
Gilbert Case White, Charlotte, N. C.
John Stephen Worley, Washington, D. C.

From Associate to Member

John Griffiths Brown, Philadelphia, Pa.
William Drumm Sell, Charleston, W. Va.

From Associate to Associate Member

John William Miller, Seattle, Wash.

From Junior to Associate Member

Nathan Benedict, Limon, Costa Rica
Claude Osgood Brown, Manila, Philippine Islands
Harold Hansen Fitting, San Francisco, Cal.
Frank Alvah Kittredge, Cloverdale, Cal.
George W Cass Lightner, Montreal, Que., Canada
Harry Clifford McClure, Toledo, Ohio
LeRoy McWethy, San Francisco, Cal.
Adelbert Philo Mills, Ithaca, N. Y.
John Robert Nichols, Cambridge, Mass.
Herbert Carleton Poore, East Braintree, Mass.
William Jenner Powell, Dallas, Tex.
Ralph Graham Shankland, Chicago, Ill.

The Secretary announced the following deaths:

James Richard Bell, of Ightham, Kent, England, elected Member, September 2d, 1896; died August 8th, 1913.

Frederic Danforth, of Gardiner, Me., elected Member, September 2d, 1891; died June 6th, 1913.

George Blinn Francis, of New York City, elected Junior, September 5th, 1883; Member, November 7th, 1888; died June 9th, 1913.

James Charles Haugh, of New Orleans, La., elected Member, February 2d, 1909; died July 6th, 1913.

Franklin Allen Hinds, of Watertown, N. Y., elected Member, May 3d, 1899; died August 23d, 1913.

Ned Herbert Janvrin, of New York City, elected Junior, October 5th, 1897; Associate Member, June 5th, 1901; Member, April 4th, 1911; died July 17th, 1913.

Alonzo Tyler Mosman, of Washington, D. C., elected Member, July 1st, 1885; died June 9th, 1913.

Henry Alexander Harris, of Princeton, N. J., elected Junior, October 31st, 1899; Associate Member, June 7th, 1905; died January 9th, 1913.

Alberto de la Torre, of Girardot, Colombia, elected Associate Member, October 3d, 1906; date of death unknown.

Samuel Stockton Bogart, of New York City, elected Associate, April 7th, 1886; died May 29th, 1913.

Adjourned.

OF THE BOARD OF DIRECTION

(Abstract)

September 3d, 1913.—President Swain in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Bates, Bush, Clarke, Edwards, Endicott, Gerber, Metcalf, Ockerson, Ridgway, Smith, Snow, and Thomson.

The appointment of a Special Committee to Study the Question of Floods, Flood Prevention, and other allied subjects, was considered.

The appointment of a Special Committee to report on Water Legislation was considered.

A payment of $25 000 to reduce the mortgage debt of the Society was authorized.

The Report of the Nominating Committee was received.

The Secretary reported that President Swain, in accordance with the authority of the Board, has appointed Messrs. Charles M. Spofford, Walter L. Webb, and Daniel W. Mead a Committee to Recommend the Award of Prizes for the year ending with the *Transactions* of July, 1913.

The formation of the Seattle Association of Members of the American Society of Civil Engineers was reported, and the Constitution of that Association, as forwarded for the consideration of the Board, was approved.

The formation of the Portland Association of Members of the American Society of Civil Engineers was reported, and the Constitution of that Association, as forwarded for the consideration of the Board, was approved.

The method of selecting the Nominating Committee was considered, and a resolution passed unanimously, that it is the sense of the Board that there should be no change at this time in the method heretofore used, and the Secretary was instructed to proceed with the issue of circulars, etc., in the usual manner.

The resignations of 2 Members, 1 Associate Member, and 2 Juniors were accepted.

Ballots for membership were canvassed, resulting in the election of 13 Members, 40 Associate Members, 16 Juniors, and the transfer of 12 Juniors to the grade of Associate Member.

Twenty-one Associate Members and 2 Associates were transferred to the grade of Member, and 1 Associate was transferred to the grade of Associate Member.

Adjourned.

ANNOUNCEMENTS

The House of the Society is open from 9 A. M. to 10 P. M., every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

FUTURE MEETINGS

October 1st, 1913.—8.30 P. M.—A regular business meeting will be held, and a paper by William J. Wilgus, M. Am. Soc. C. E., entitled "Physical Valuation of Railroads," will be presented for discussion. This paper was printed in *Proceedings* for May, 1913.

October 15th, 1913.—New Orleans Meeting.—The meeting of the Society scheduled for October 15th, 1913, will be held in New Orleans, La., and a paper by W. E. Fuller, M. Am. Soc. C. E., entitled "Flood Flows," will be presented for discussion. Mr. Fuller's paper was printed in *Proceedings* for May, 1913.

In connection with this Meeting the Louisiana Members have arranged a programme covering Wednesday, Thursday, Friday, and Saturday, October 15th to 18th, inclusive, and it is hoped that there will be a large attendance of the members and the ladies of their families.

Arrangements for this—the first Society Meeting, other than the Annual Convention, held away from headquarters—are in the hands of the following:

Local Committee.—Frank M. Kerr, J. F. Coleman, E. L. Jahncke, Sidney F. Lewis, Arsene Perrilliat, A. M. Shaw, W. H. Williams, A. M. N. Blamphin.

The address of the Committee is Room 920, Hibernia Bldg., New Orleans, La.

Headquarters.—The Headquarters of the Society will be the Grunewald Hotel.

Hotel Reservations.—It is very desirable, in view of the fact that another Convention is to be held in New Orleans overlapping the dates for this Meeting, that hotel reservations be made as soon as possible, addressing the Local Committee. Prompt attention in this matter is urged, not only that the best accommodations available may be secured, but also to enable the Committee to know the number who will take part in the various excursions and entertainments.

Programme.—The following programme has been arranged. It is subject to minor changes, and it is here printed for the information of the Membership.

It is hoped that Members may arrange to arrive in New Orleans on Tuesday, October 14th.

New Orleans Meeting (Continued)

Wednesday, October 15th.—10 A. M.—Meeting of Society.

(1) Brief Welcoming Addresses by the Governor of Louisiana, the Mayor of New Orleans, and the President of the Louisiana Engineering Society.

(2) Brief talk by a local Member descriptive of topographical peculiarities of New Orleans and vicinity, and calling attention to technical practice in this territory which, by reason of local conditions, is different from the usual standard practice elsewhere.

(3) Address on the Problem of Mississippi River Control.

Afternoon: Automobile trip through the City.

8 P. M. Meeting of Society.

(1) Paper entitled "Flood Flows," by Weston E. Fuller, M. Am. Soc. C. E.

(2) Illustrated address on the Sewerage, Drainage, and Water Works of New Orleans.

Thursday, October 16th.—10 A. M. River trip in New Orleans Harbor; Lunch on steamer. Automobile trip from steamer to Water Filtration Plant, then to a typical Drainage Pumping Station and to other points of Engineering interest, returning to hotels about 5:30 P. M.

8 P. M. Smoker and Entertainment, which it is hoped the ladies of the party will attend.

Friday, October 17th.—In the morning, under special guides, parties will be taken through the old French Quarter.

In the afternoon a Garden Party will be given at the Country Club. Golf on Links of Country Club for those who play that game.

8:30 P. M. Dinner Dance.

Saturday, October 18th.—The day will be devoted to a visit to Avery's Island Salt Mines near New Iberia, La., by special train, with probable stop-over to inspect a large sugar estate. Returning to New Orleans about 6 P. M.

Excursion to Panama.—It has been suggested that some of the Members may desire to visit the Panama Canal in connection with this meeting.

The United Fruit Company's steamers sail from New Orleans to Panama on Saturday morning, and reservations will be made by the Local Committee for those who will inform them of their intention to make the trip.

November 5th, 1913.—8.30 P. M.—This will be a regular business meeting. Two papers will be presented for discussion, as follows: "Concrete Bridges: Some Important Features in Their Design," by Walter M. Smith, Sr., M. Am. Soc. C. E., and Walter M. Smith, Jr.,

Jun. Am. Soc. C. E.; and "The Effect of Saturation on the Strength of Concrete," by J. L. Van Ornum, M. Am. Soc. C. E.

These papers were printed in *Proceedings* for August, 1913.

November 19th, 1913.—8.30 P. M.—At this meeting a paper by Richard R. Lyman, Assoc. M. Am. Soc. C. E., entitled "Measurement of the Flow of Streams by Approved Forms of Weirs, with New Formulas and Diagrams," will be presented for discussion.

This paper is printed in this number of *Proceedings.*

SEARCHES IN THE LIBRARY

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

In reference to this work, the Appendices* to the Annual Reports of the Board of Direction for the years ending December 31st, 1906, and December 31st, 1910, contain summaries of all searches made to date.

PAPERS AND DISCUSSIONS

Members and others who take part in the oral discussions of the papers presented are urged to revise their remarks promptly. Written communications from those who cannot attend the meetings should be sent in at the earliest possible date after the issue of a paper in *Proceedings.*

All papers accepted by the Publication Committee are classified by the Committee with respect to their availability for discussion at meetings.

Papers which, from their general nature, appear to be of a character suitable for oral discussion, will be published as heretofore in

* *Proceedings*, Vol. XXXIII, p. 20 (January, 1907); Vol. XXXVII, p. 28 (January, 1911).

Proceedings, and set down for presentation to a future meeting of the Society, and, on these, oral discussions, as well as written communications, will be solicited.

All papers which do not come under this heading, that is to say, those which from their mathematical or technical nature, in the opinion of the Committee are not adapted to oral discussion, will not be scheduled for presentation to any meeting. Such papers will be published in *Proceedings* in the same manner as those which are to be presented at meetings, but written discussions, only, will be requested for subsequent publication in *Proceedings* and with the paper in the volumes of *Transactions.*

The Board of Direction has adopted rules for the preparation and presentation of papers, which will be found on page 429 of the August, 1913, *Proceedings.*

LOCAL ASSOCIATIONS OF MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

San Francisco Association

The San Francisco Association of Members of the American Society of Civil Engineers holds regular bi-monthly meetings, with banquet, and weekly informal luncheons. The former are held at 6 P. M., at the Palace Hotel, on the third Friday of February, April, June, August, October, and December, the last being the Annual Meeting of the Association.

Informal luncheons are held at 12.15 P. M. every Wednesday, and the place of meeting may be ascertained by communicating with the Secretary of the Association, E. T. Thurston, Jr., M. Am. Soc. C. E., 713 Mechanics' Institute, 57 Post Street.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in San Francisco, and any such member will be gladly welcomed as a guest.

Colorado Association

The meetings of the Colorado Association of Members of the American Society of Civil Engineers are held on the second Saturday of each month, except July and August. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary, R. W. Toll, Jun. Am. Soc. C. E., 700 Tramway Building, Denver, Colo. The meetings are usually preceded by an informal dinner. Members of the American Society of Civil Engineers will be welcomed at these meetings.

Weekly luncheons are held on Wednesdays, and, until further notice, will take place at the Colorado Traffic Cub.

Visiting members are urged to attend the meetings and luncheons.

Atlanta Association

On March 14th, 1912, the Atlanta Association of Members of the American Society of Civil Engineers was organized, with the following

officers: Arthur Pew, President; William A. Hansell, Jr., Secretary; and Messrs. James N. Hazlehurst and Alexander Bonnyman, Members of the Executive Committee. The Association will hold its meetings in the house of the University Club.

Seattle Association

On June 30th, 1913, the Seattle Association of Members of the American Society of Civil Engineers was organized with the following officers: Samuel H. Hedges, President; Ernest B. Hussey, Vice-President; and Joseph Jacobs, Secretary-Treasurer.

Philadelphia Association

At its meeting of June 4th, 1913, the Board of Direction of the Society considered and approved the proposed Constitution of the Philadelphia Association of Members of the American Society of Civil Engineers.

Portland Association

(Abstract of Minutes of Meeting)

June 18th, 1913.—At a meeting held at the Commercial Club, Portland, Ore., F. I. Fuller, M. Am. Soc. C. E., in the chair; Charles J. McGonigle, M. Am. Soc. C. E., Secretary; and present, also, 22 members of the Society, the following business was transacted:

E. G. Hopson, M. Am. Soc. C. E., Chairman of the Committee on Organization, read a letter from Charles Warren Hunt, Secretary of the American Society of Civil Engineers, and recommended that the constitution and by-laws of the San Francisco Association be adopted with amendments to suit the local conditions.

A resolution was adopted to organize formally a Portland Association of Members of the American Society of Civil Engineers, to be effective if 40 members become enrolled.

The constitution and by-laws of the San Francisco Association were read by the Secretary, voted on article by article, and, with necessary amendments, adopted by unanimous vote.

A Committee on Nomination, Mr. Mason, Chairman, recommended the election of the following officers, and they were elected by unanimous vote:

President, E. G. Hopson,
First Vice-President, W. S. Turner,
Second Vice-President, D. D. Clarke,
Treasurer, G. B. Hegardt,
Secretary, Charles J. McGonigle.

Mr. Hopson took the chair.

A motion was adopted that the Board of Directors of the Association offer to act in an advisory capacity to the Mayor and Commissioners of Portland in the selection of a City Engineer.

(In accordance with this motion, the Board of Directors met on June 19th, 1913, and instructed the President, Mr. Hopson, to consult with the Mayor and Commissioners in relation to the appointment of a City Engineer.)

A motion was adopted that it is the sense of this Association that the City Engineer of Portland should receive a salary commensurate with the position and favorably comparable with the salaries paid to City Engineers in other cities.

Adjourned.

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms, and at all meetings:

American Institute of Mining Engineers, 29 West Thirty-ninth Street, New York City.

American Society of Mechanical Engineers, 29 West Thirty-ninth Street, New York City.

Architekten-Verein zu Berlin, Wilhelmstrasse 92, Berlin W. 66, Germany.

Associação dos Engenheiros Civis Portuguezes, Lisbon, Portugal.

Australasian Institute of Mining Engineers, Melbourne, Victoria, Australia.

Boston Society of Civil Engineers, 715 Tremont Temple, Boston, Mass.

Brooklyn Engineers' Club, 117 Remsen Street, Brooklyn, N. Y.

Canadian Society of Civil Engineers, 413 Dorchester Street, West, Montreal, Que., Canada.

Civil Engineers' Society of St. Paul, St. Paul, Minn.

Cleveland Engineering Society, Chamber of Commerce Building, Cleveland, Ohio.

Cleveland Institute of Engineers, Middlesbrough, England.

Dansk Ingeniorforening, Amaliegade 38, Copenhagen, Denmark.

Engineers' and Architects' Club of Louisville, Ky., 303 Norton Building, Fourth and Jefferson Streets, Louisville, Ky.

Engineers' Club of Baltimore, Baltimore, Md.

Engineers' Club of Minneapolis, 17 South Sixth Street, Minneapolis, Minn.

Engineers' Club of Philadelphia, 1317 Spruce Street, Philadelphia, Pa.

Engineers' Club of St. Louis, 3817 Olive Street, St. Louis, Mo.

Engineers' Club of Toronto, 96 King Street, West, Toronto, Ont., Canada.

Engineers' Society of Northeastern Pennsylvania, 302 Board of Trade Building, Scranton, Pa.

Engineers' Society of Pennsylvania, 219 Market Street, Harrisburg, Pa.

Engineers' Society of Western Pennsylvania, 2511 Oliver Building, Pittsburgh, Pa.

Institute of Marine Engineers, 58 Romford Road, Stratford, London, E., England.

Institution of Engineers of the River Plate, Buenos Aires, Argentine Republic.

Institution of Naval Architects, 5 Adelphi Terrace, London, W. C., England.

Junior Institution of Engineers, 39 Victoria Street, Westminster, S. W., London, England.

Koninklijk Instituut van Ingenieurs, The Hague, The Netherlands.

Louisiana Engineering Society, 321 Hibernia Bank Building, New Orleans, La.

Memphis Engineering Society, Memphis, Tenn.

Midland Institute of Mining, Civil and Mechanical Engineers, Sheffield, England.

Montana Society of Engineers, Butte, Mont.

North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne, England.

Oesterreichischer Ingenieur- und Architekten-Verein, Eschenbachgasse 9, Vienna, Austria.

Pacific Northwest Society of Engineers, 803 Central Building, Seattle, Wash.

Rochester Engineering Society, Rochester, N. Y.

Sachsischer Ingenieur- und Architekten-Verein, Dresden, Germany.

Sociedad Colombiana de Ingenieros, Bogota, Colombia.

Sociedad de Ingenieros del Peru, Lima, Peru.

Societe des Ingenieurs Civils de France, 19 Rue Blanche, Paris, France.

Society of Engineers, 17 Victoria Street, Westminster, S. W., London, England.

Svenska Teknologforeningen, Brunkebergstorg 18, Stockholm, Sweden.

Tekniske Forening, Vestre Boulevard 18–1, Copenhagen, Denmark.

Western Society of Engineers, 1737 Monadnock Block, Chicago, Ill.

ACCESSIONS TO THE LIBRARY

(From August 1st to September 2d, 1913)

DONATIONS*

PRINCIPLES AND METHODS OF MUNICIPAL TRADING.

By Douglas Knoop. Cloth, 9 x 5¾ in., 17 + 409 pp. London, Macmillan and Co., Limited, 1912. $3.25.

Municipal trading, as discussed by the author, relates to economic undertakings which are self-supporting, and the book embodies, it is stated, the results of his work and investigations on the subject as Langton Fellow at the University of Manchester. His aim, the preface states, has been to show what has happened in the past and what is being done at the present in municipal trading, and to make a survey of the most important problems relating to the subject, his inquiries being practically limited to Great Britain and Germany. To this end he has described the policies and methods commonly adopted by local authorities in their trading undertakings, the various reasons which have led to the development of such trading, and the financial aspects of the problem, as well as the results achieved by such enterprises. The Chapter headings are: The Scope of Municipal Trading; The Development of Municipal Trading; The Extent of Municipal Trading; The Management of Municipal Trades; The Financial Aspects of Municipal Trading; The Selling Policies of Municipal Trades; The Labour Policy of Municipal Trades; The Results of Municipal Trading; Summary and Conclusion; Appendix A, Bibliographical Note; Appendix B, List of Municipal Tramway Undertakings in the United Kingdom; Appendix C, Hourly Traffic on Typical Manchester and Glasgow Train Routes; Appendix D, Supplementary Statistics Concerning Municipal Trading during 1910-11; Index.

PLANS OF GRAIN ELEVATORS.

Third Edition. Cloth, 12¼ x 9¼ in., illus., 378 pp. Chicago, Grain Dealers' Journal, 1913. $5.00.

In a sub-title this volume is described as "a book in the interests of the construction of better grain elevators", and the preface states that it is designed to assist grain dealers in providing and maintaining first-class facilities for storing, handling, and cleaning grain. Plans and views of grain elevators and grain storehouses at various places and for various uses are given, together with detailed descriptions of the foundations, mechanical equipment, power plant and transmission systems, scales, arrangement of office and working floors, etc., of such buildings. The Contents are: Terminal Elevators; Transfer and Cleaning Elevators; Country Elevators.

CONCRETE ROADS AND PAVEMENTS.

By E. S. Hanson. Cloth, 8 x 5 in., illus., 227 pp. Chicago, The Cement Era Publishing Company, 1913. $1.00.

A complete revision of the science of roadmaking has been made necessary within the last few years, it is stated, on account of the high-speed vehicles now in use, the wide tires of which develop great suction. Concrete has come to be recognized, it is further stated, as the best material to meet these new conditions, and this volume, which is said to be a compilation of facts, has been issued as a convenient handbook containing everything of value that is known to date on the subject. It is hoped that this book will serve not only to stimulate the construction of concrete roadways, but that it will furnish roadmakers with specific data as to the best class of concrete roads and pavements. The Contents are: Concrete as a Road Material; The Construction of Concrete Roadways; The Roads of Wayne County, Michigan; Cost of Concrete Roads in Illinois; Other Examples of Concrete Roads; Some Data on City Pavements; Reinforced Concrete Pavements; Concrete in Combination with Other Materials; Patented Concrete Pavements; The Theory and Practice of Joints; Some Tests on Concrete as a Roadway Material; Bridges and Culverts; Sidewalks, Curbs, and Gutters; Appendix A, Specifications of National Association of Cement Users—Roads and Pavements; Appendix B, Wayne County Specifications; Appendix C, Mason City Specifications; Appendix D, Specifications of Illinois Highway Commission; Appendix E, Specifications for Blome Granitoid Pavement; Appendix F, Specifications for Blome Granocrete Pavement; Appendix G, Specifications for Bitustone Pavement; Appendix H, Specifications of Dolarway Pavement; Appendix I, Specifications for Hassamite; Appendix J, Specifications for Bridges and Culverts; Appendix K, Specifications for Sidewalks; Appendix L, Specifications for Curbs and Gutters.

*Unless otherwise specified, books in this list have been donated by the publishers.

FABRICATION DE L'ACIER.

Par H. Noble. Deuxième Edition, Revue et Augmentée. Paper, 10 x 6½ in., illus., 7 + 632 pp. Paris, H. Dunod et E. Pinat, 1913. 25 francs.

The author states that this volume is devoted to a general study of the metallurgy of steel, particularly of the machinery and apparatus, including the latest improvements, used in steelworks. In discussing this machinery he states that he has confined his study to the general principles of the subject, offering no criticism of the various types described and avoiding the details of their mechanical construction. The Chapter headings are: Propriétés Générales des Aciers; Etude Théorique de la Conversion; Fontes de Conversion, Cubilots, Mélangeurs; Chaux d'Aciérie; Etude Pratique de la Conversion; Recarburation, Coulée en Poche; Etablissement des Convertisseurs; Garnissages Basiques; Garnissages Acide; Machines Soufflantes; Etude Théorique de l'Affinage sur Sole; Matières Premières Employées dans l'Affinage sur Sole; Etude Pratique de l'Affinage sur Sole; Chauffage des Fours Martin; Construction des Fours Martin; Entretien des Fours Martin; Procédés Mixtes; Lingots d'Acier; Coulée en Lingotières; Poches et Appareils de Coulée; Personnel, Compatibilité.

ECONOMIES IN BRICKYARD CONSTRUCTION AND OPERATION.

By Ellis Lovejoy. Cloth, 7¾ x 5½ in., 72 pp. Indianapolis, T. A. Randall & Co., 1913. $1.00.

The subject-matter contained in this volume first appeared serially in *The Clay-Worker,* and is now issued in book form for handy use in the brickyard. The author states that as the great waste in the average brickyard is the result of lack of experience, extravagance in construction, and operation, insufficient capital, quality and quantity of clay used, need of cost systems and records, etc., he has written this book as a sort of review of many investigations of such details in plants of various types and at various places. The Contents are: Brick Business Not so Simple as It Seems; Economies in Clay Gathering; Economies in the Preparation of the Clay; Economies in the Feeding, Pugging and Manufacture; Economies in Conveying and Drying; Economies in Setting; Economies in the Burning; Drawing Bricks from Kilns and Sorting; Use of Producer Gas in Burning.

THE PRACTICAL METALLOGRAPHY OF IRON AND STEEL.

By John S. G. Primrose. Boards, 8½ x 5½ in., illus., 129 pp. Manchester, England, The Scientific Publishing Company. 3 shillings.

This book, it is stated, comprises those chapters contained in the second edition of Sexton's "The Metallurgy of Iron and Steel", which relate to metallography. The subject-matter has been revised and rewritten by the author, and is published as a separate volume for use as reference by the student in metallurgical engineering and as an aid to those who are commencing a study of metallography by means of the microscope, being stated to be an accurate résumé of present knowledge of the subject. The chapter on metallographic apparatus, it is stated, is intended as a guide for those who contemplate the purchase of an outfit for use in a works laboratory, and includes a detailed description of the use of the various machines. The Contents are: Microstructure of Iron and Steel; Constitution of Iron and Steel; Heat Treatment of Iron and Steel; Micrographic Examination of Failures; Appendix I, Metallographic Apparatus and Its Manipulation; Appendix II, Bibliography; Index.

AN INTRODUCTION TO THE MATHEMATICAL THEORY OF HEAT CONDUCTION:

With Engineering and Geological Applications. By L. R. Ingersoll and O. J. Zobel. Cloth, 8½ x 5¾ in., illus., 6 + 171 pp. Boston, New York, Chicago, London, Ginn and Company, 1913. $1.60.

Although written primarily to meet the need of a suitable textbook on the subject, the preface states that the aim of the authors in presenting this book has been two-fold: First, a development of the subject with special reference to the needs of the student who has neither the time nor mathematical preparation to pursue the study at great length, to which end, it is said, fewer types of problems have been used and less stress has been placed on the purely mathematical derivations such as uniqueness, existence and convergence theorems; and second, the presentation of clear and specific applications of the many theoretical and practical applications of which the results are susceptible. It is hoped, that the subject-matter may prove of interest to engineers as well as to students, as many applications have been chosen with special reference to their technical importance, for example, the "theory of the fire-proof wall". The Contents are: Introduction; The Fourier Con-

duction Equation; The Steady State: One Dimension; The Steady State: More Than One Dimension; Periodic Flow of Heat in One Dimension; Fourier's Series; The Linear Flow of Heat; The Flow of Heat in More Than One Dimension; The Formation of Ice; Appendices A to F; Index.

GAS ANALYSIS.

By L. M. Dennis. Cloth, $7\frac{3}{4}$ x 5 in., illus., 16 + 434 pp. New York, The Macmillan Company, 1913. $2.10.

The preface states that, in its general plan, this book follows the last edition of the English translation of Hempel's "Methods of Gas Analysis", full descriptions of his methods of both technical and exact gas analysis having been incorporated in the text with his permission, with modifications, in some cases, of the apparatus and manner of its manipulation. Procedures for determining most of the gases to be met with in analytical work are described, including certain methods of exact analysis adapted to specific determinations, and as no attempt has been made to include descriptions of all the new methods, numerous references are made in the text to original articles. The author has not included, it is stated, the separation of the gases in the argon group for the reason that rapid and simple methods for such determination have not as yet been perfected. As much is said to depend on the skill with which the analytical work is performed, the manipulation of each of the generally used type of apparatus is discussed in detail. The Contents are: The Collection and Storage of Gases; The Measurement of Large Samples of Gas; The Measurement of Gases; The Determination of a Specific Gravity of a Gas; Arrangements and Fittings of the Laboratory; The Hempel Apparatus for Exact Gas Analysis with Mercury as the Confining Liquid; the Construction and Connection of Apparatus; Purification of Mercury; Absorption Apparatus for Use with Large Volumes of Gas; The Combustion of Gases; The Determination of Gases by Combustion; Properties of the Various Gases and Methods for Their Determination; Flue Gas Analysis; Illuminating Gas, Fuel Gas; The Determination of the Heating Value of Fuel; Acetylene Gas; Examination of Atmospheric Air; The Analysis of Saltpeter and Nitric Acid Esters (Nitroglycerine, Gun-Cotton) with the Nitrometer; The Lunge Nitrometer; Tables; Indexes.

ANNUAL INTERNATIONAL NUMBER OF "THE SHIPBUILDER," 1913:

A Survey of the Scientific and Technical Progress in Naval Architecture and Marine Engineering. Cloth, 10 x $7\frac{1}{2}$ in., illus., 320 pp. Newcastle-on-Tyne, "The Shipbuilder" Press; London, Gilbert-Wood Press, 1913. $1.45.

This volume, the first number of which was published in June, 1912, is stated to be a concise and comprehensive survey of the world's work in shipbuilding and allied industries for 1913. It is intended as a reference book on the more technical phases of the industry, and contains many papers on the subject read before British and foreign scientific and technical societies. It is also intended as a résumé of the latest developments in naval architecture and marine engineering in Great Britain.

SIMPLIFIED FORMULAS AND TABLES

For Floors, Joists and Beams; Roofs, Rafters and Purlins. By N. Clifford Ricker. Cloth, $9\frac{1}{4}$ x 6 in., illus., 6 + 77 pp. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Limited, 1913. $1.50.

The author states that the formulas generally contained in textbooks on the mechanics of engineering materials, for rupture and deflection in structural problems, are inconvenient, because of the large numbers which have to be used in their computation. By transforming these formulas and changing lengths from inches to feet, loads from pounds to tons, constants for material from pounds to tons, and bending moments from inch-pounds to foot-tons, thus simplifying the results, he gives in this volume, it is stated, a simple system of formulas and tables which can be applied by using a slide rule or a four-place table of logarithms, and which he hopes will be of use to architects and engineers. Tables are included for rectangular cross-sections of timbers and standard cross-sections of cast-iron lintels, as well as of four-place logarithms, together with a series of numerical examples which have been carefully worked out for the application of these formulas. A partial list of Contents is as follows: Ordinary Formulas for Beams; Notation in Ordinary Formulas; Table A of Ordinary Formulas; Inconveniences in Use; Method of Simplifying Formulas; Notation in Simplified Formulas; Method of Simplification; etc., etc.

GRAPHICS AND STRUCTURAL DESIGN.

By H. D. Hess. Cloth, 9¼ x 6 in., illus., 8 + 426 pp. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Limited, 1913. $3.00.

A knowledge of this subject is necessary to the designer, the preface states, while acquaintance with the methods used to determine the stresses in, and the design of, structures is desirable for others in designing for strength, whether for structures or machines. The author states that the volume is intended for his classes in General Engineering Design in Sibley College, Cornell University, and while the treatment of the subject has been kept as general as possible, it is hoped it may prove useful as a reference book for designers whose work is not too highly specialized. The determination of stresses has not been confined to graphical means, it is stated, the usual methods having been included, and the problems discussed are those on the border line of Civil and Mechanical Engineering. The Chapter Headings are: Materials; Graphics; Stresses in Structures; Algebraic Determination of Stresses; Influence Diagrams; Tension Pieces, Compression Pieces and Beams; Columns; Girders for Conveyors; Trusses, Bents and Towers; Design of Steel Mill Buildings; Design of a Plate-Girder Railway Bridge; Crane Frames; Girders for Overhead Electric Traveling Cranes; Reinforced Concrete; Foundations; Chimneys; Retaining Walls; Bins; Shop Floors; Walls and Roofs; Specifications; Problems; Index.

THE THEORY AND DESIGN OF STRUCTURES:

A Text-Book for the Use of Students, Draughtsmen, and Engineers Engaged in Constructional Work. By Ewart S. Andrews. Third Edition. Cloth, 8¾ x 5¾ in., illus., 12 + 618 pp. London, Chapman & Hall, Ltd., 1913. 9 shillings.

This textbook, it is stated, is based on lecture notes used by the author in his classes and from examples in actual practice. The book is said to be written largely from a graphical standpoint, but many of the problems are treated mathematically. It contains, the author states, some matter which is not found in English textbooks in common use, such as, the French or St. Venant method of dealing with combined bending and shear stresses, the general theory of curved beams and non-symmetrical beams, and the strength of heterogeneous structures as reinforced concrete, a special effort having been made to make the chapter on struts and columns clear. Attention is particularly called to the worked problems which are said to be a feature of the book. In this, the third edition, all the new matter, the most important of which is stated to be the note on Stanton's experiments on wind pressure and the new exercises, is contained in an Appendix. The notation in the chapter on Reinforced Concrete has been made to agree, it is said, with that proposed by the Concrete Institute. The Chapter headings are: Stress, Strain, and Elasticity; Principles of Design, Working Stresses, etc., Wind Pressure; Forces, Areas, and Moments; Riveted Joints and Connections; Bending Moments and Shearing Forces in Beams; Stresses in Beams; Bending Moments and Shearing Forces for Rolling Loads; Deflection of Beams; Fixed and Continuous Beams; Distribution of Shearing Stresses in Beams; Framed Structures; Columns, Stanchions, and Struts; Suspension Bridges and Arches, Masonry Structures; Reinforced Concrete and Similar Structures; Design of Steelwork for Buildings, etc.; Design of Roofs; Design of Bridges and Girders; Appendix I; Appendix II, Tables of Properties of British Standards; Exercises; Index.

FURTHER PROBLEMS IN THE THEORY AND DESIGN OF STRUCTURES:

An Advanced Text-Book for the Use of Students, Draughtsmen, and Engineers Engaged in Constructional Work. By Ewart S. Andrews. Cloth, 8¾ x 5¾ in., illus., 8 + 236 pp. London, Chapman & Hall, Ltd., 1913. 7 shillings, 6 pence.

As several recent problems in construction which are of interest and importance to engineers were omitted in the author's "Theory and Design of Structures", this book has been written, it is stated, as a supplement to that volume, the general treatment of the subject-matter being the same in both. All the steps in the mathematical deductions have been given, it is said, even at the risk of criticism, as an aid to the student. The first portion of the book deals, it is stated, with the development of the method of Influence Lines. This is followed by the Principle of Work and its application to deflections of framed structures, redundant frames, and rigid arches; and the last part is devoted to a discussion of Portals and Wind Bracings, and Secondary Stresses. The Contents are: Influence Lines; Influence Lines for Simply Supported Frames; Influence Lines for Fixed and Con-

tinuous Beams; Influence Lines for Arches and Suspension Bridges; Internal Work; Deflections of Framed Structures; Stresses in Redundant Frames; Stresses in Rigid or Elastic Arches; Stresses in Portals and Wind Bracings; Secondary Stresses in Structures; Index.

THE ELEMENTS OF SPECIFICATION WRITING:

A Text-Book for Students in Civil Engineering. By Richard Shelton Kirby. Cloth, 9¼ x 6 in., 7 + 125 pp. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Limited, 1913. $1.25.

This book, it is stated, is the outgrowth of a series of lectures delivered by the author before the Senior Class in Civil and Sanitary Engineering in Sheffield Scientific School, and is a textbook on specification writing (not a collection of specifications) which it is hoped will prove of value to the young engineer as well as the student. The important features of the text are said to be the concise description of the fundamentals of a contract with its plans and specifications; the chapters devoted to Advertisement and Proposals; the thorough exposition, from an engineering viewpoint, of the General Clauses of a specification, including the citation and discussion of cases illustrating their application, as well as a number of model clauses; the practical suggestions concerning Specific Clauses, of which outlines for nine construction projects are given; and the classified list of references to recent articles on the subject in technical journals and in publications of technical societies, contained in the Appendix. The Contents are: Introduction; Contract and Bond; Advertisement (or Notice to Contractors) and Information for Bidders; Proposal; The Composition of Specifications; General Clauses—Specifications and Plans; The Engineer During Construction; The Contractor and His Workmen; The Contractor's Miscellaneous Responsibilities; Progress of Work; Terms of Payment; Specific Clauses; Outlines of Specific Clauses; Appendix: References; Index.

Gifts have also been received from the following:

Alabama-State Highway Dept. 1 pam.
Am. Electrochemical Soc. 1 vol.
Am. Ry. Eng. Soc. 1 vol.
Assoc. Internationale de Froid. 1 pam.
Assoc. of Ontario Land Surv. 1 pam.
Assoc. of Transportation and Car Accounting Officers. 1 pam.
Bangor, Me.-Water Board. 1 pam.
Belgium-Ministère des Chemins de Fer, Postes et Télégraphes. 3 bound vol.
Berlin Kgl. Technische Hochschule. 1 pam.
Bihar and Orissa, India-Irrig. Dept. 1 vol.
Birnie, R. S. 4 pam.
Bridge Builders' Soc. 1 pam.
British Columbia-Minister of Mines. 1 vol.
Buffalo, Rochester & Pittsburgh Ry. Co. 1 pam.
Canada-Dept. of Mines. 1 vol., 1 pam.
Canada-Minister of Rys. and Canals. 12 pam.
Central Ry. Club. 1 pam.
Chicago, Ill.-Dept. of Public Works. 1 bound vol.
Congrès des Ingenieurs en Chef des Associations de Propriétaires d'Appareils à Vapeurs. 1 pam.
Connecticut Soc. of Civ. Engrs. 1 pam.
Corry, T. A. 1 map.
Crosby, W. W. 1 pam.
Dugan, D. H. 3 bound vol.
Egypt-State Rys. and Telegraphs Comm. 1 pam.
Fall River, Mass.-City Clerk. 1 bound vol.
Fifth Ave. Assoc. 1 pam.
Follett, W. W. 1 pam.
Fuster, José M^a. 2 bound vol.
Gen. Ry. Signal Co. 1 bound vol.
Goltra, W. F. 1 pam.
Goodrich, E. P. 2 pam.
Hartford, Conn.-Water Commrs. 1 vol.
Haverhill, Mass.-Board of Water Commrs. 1 pam.
Illinois-R. R. and Warehouse Comm. 2 bound vol.
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Institution of Civ. Engrs. 1 bound vol.
Iowa-State College-Eng. Exper. Station. 2 pam.
Iron and Steel Inst. 1 bound vol.
Japan-Chf. of Documents and Archives. 1 vol.
Kansas City, Mo.-Fire and Water Commrs. 1 vol.
Kansas City, Mo.-Hospital and Health Board. 1 vol.
Kansas Eng. Soc. 1 vol.
Kelly, Hugh A. 1 pam.
Krupp, Fried., Aktiengesellschaft. 2 bound vol.
Lehigh Valley R. R. Co. 2 pam.
Liverpool, England-Water Engr. 1 bound vol.
Liverpool Eng. Soc. 1 pam.
Manchester, N. H. - Board of Water Commrs. 1 vol.
Marlborough, Mass.-City Clerk. 7 bound vol., 2 vol.
Maryland-State Dept. of Health. 1 pam.
Massachusetts-Bureau of Statistics. 1 bound vol.
Massachusetts-Metropolitan Park Comm. 1 bound vol.
Massachusetts-State Board of Health. 2 pam.
Mellon Inst. of Industrial Research. 1 pam.
Merchants Assoc. of N. Y. 1 vol.
Michigan Coll. of Mines. 1 vol.
Missouri Univ.-Eng. Exper. Station. 1 pam.

Montana-State Board of Health. 1 vol.
Nashville, Tenn.-Board of Public Works. 3 bound vol., 8 vol.
National Board of Fire Underwriters. 14 pam.
National Fire Protection Assoc. 2 pam.
Natural Ice Assoc. of America. 4 bound vol., 10 pam.
New Jersey-Board of Equalization of Taxes. 1 pam.
New South Wales-Metropolitan Board of Water Supply and Sewerage. 1 vol.
New York City-Board of Water Supply. 2 bound vol.
New York City-Dept. of Docks and Ferries. 1 bound vol.
New York State-Commrs. of Fire Island State Park. 2 pam.
New York State-Public Service Comm., Second Dist. 11 pam.
New York R. R. Club. 1 pam.
Oesterreichischer Ingenieur- und Architekten Verein. 1 pam.
Ohio-Geol. Survey. 1 bound vol.
Ontario, Canada-Minister of Public Works. 4 pam.
Permanent Inter. Assoc. of Navigation Congresses. 1 bound vol., 3 pam., 1 map.
Philadelphia, Pa. - Transit Commrs. 1 vol.
Philadelphia Rapid Transit Co. 1 pam.
Philippine Islands-Board of Rate Regulation. 1 pam.
Philippine Islands - Weather Bureau. 1 vol.
Portland, Me.-Dept. of Public Works. 1 pam.
Ramsbotham, J. F. 2 bound vol.
Reibling, W. C. 1 pam.
St. Paul, Minn.-Board of Water Commrs. 1 vol.
Salt Lake City, Utah-City Recorder. 1 bound vol., 1 pam.
Sandusky, Ohio-City Auditor. 1 pam.
São Paulo, Brazil - Commissão Geographica e Geologica. 1 vol.
Smithsonian Institution. 5 pam.
Stuart, Inglis. 1 bound vol.
Sydney, New South Wales-City Surv. 20 pam.
Texas-State Levee and Drainage Board. 1 pam., 8 maps.
Turner, C. A. P. 1 bound vol.
Tyrrell, H. G. 1 pam.
U. S.-Bureau of Mines. 7 pam.
U. S.-Bureau of Ry. Economics. 14 pam.
U. S.-Chf. of Engrs. 38 specif.
U. S.-Coast and Geodetic Survey. 1 pam.
U. S.-Commr. of Education. 2 bound vol.
U. S.-Geol. Survey. 6 vol., 8 pam.
U. S.-Interstate Commerce Comm. 1 pam.
U. S.-Lake Survey Office. 1 pam.
U. S.-Office of Public Roads. 1 pam.
U. S.-Ordnance Dept. 2 bound vol., 5 pam.
U. S.-Secy. of the Interior. 1 pam.
U. S.-Weather Bureau. 1 vol.
University Club. 1 bound vol.
Virginia-Geol. Survey. 1 vol.
Western Canada Irrig. Assoc. 4 pam.
Whitman, Ezra B. 1 bound vol.
Woburn, Mass.-City Clerk. 1 bound vol.

BY PURCHASE

Petroleum : A Treatise on the Geographical Distribution and Geological Occurrence of Petroleum and Natural Gas ; the Physical and Chemical Properties, Production, and Refining of Petroleum and Ozokerite ; the Characters and Uses, Testing, Transport and Storage of Petroleum Products ; and the Legislative Enactments Relating Thereto ; Together with a Description of the Shale Oil and Allied Industries ; and a Full Bibliography. By *Sir* Boventon Redwood. Third Edition, Revised and Enlarged. 3 Vol. J. B. Lippincott Co., Philadelphia ; Charles Griffin & Co., Limited, London, 1913.

Untersuchungen über den Zusammenhang der Erscheinungen in Wasserläufen auf Grund hydrometrischer Erhebungen, zur Förderung des Flussbaues und seines Unterrichtes für Studierende und Ingenieure. Von C. Krischan. 2 Vol. Leykam, Graz, 1912.

Mitteilungen über Forschungsarbeiten auf dem Gebiete des Ingenieurwesens insbesondere aus den Laboratorien der technischen Hochschulen. Herausgegeben vom Verein deutscher Ingenieure. Hefte 135–137. Julius Springer, Berlin, 1913.

Chloride of Lime in Sanitation. By Albert H. Hooker. John Wiley & Sons, Inc., New York; Chapman & Hall, Limited, London, 1913.

Steam Power Plant Engineering. By G. F. Gebhardt. Fourth Edition. John Wiley & Sons, Inc., New York; Chapman & Hall, Limited, London, 1913.

Mathematical Monographs; Nos. 1–12. Edited by Mansfield Merriman and Robert S. Woodward. John Wiley & Sons, New York; Chapman & Hall, London, 1906-13.

The Basic Open-Hearth Steel Process. By Carl Dichmann. Translated and Edited by Alleyne Reynolds. D. Van Nostrand Co., New York, 1913.

Universal Directory of Railway Officials, 1913. Compiled from Official Sources under the Direction of S. Richardson Blundstone. The Directory Publishing Company, Limited, London.

Das Maschinen-Zeichnen. Von A. Riedler. Zweite, neubearbeitete Auflage. Julius Springer, Berlin, 1913.

Lehrbuch des Hochbaues. Herausgegeben von Esselborn. Erster Band. Zweite, stark vermehrte Auflage. Wilhelm Engelmann, Leipzig, 1913.

SUMMARY OF ACCESSIONS

(From August 1st to September 2d, 1913)

Donations (including 25 duplicates)	325
By purchase	26
Total	351

MEMBERSHIP

ADDITIONS

(From August 8th to September 4th, 1913)

MEMBERS		Date of Membership.
GRIFFITH, JOHN HOWELL. Engr.-Physicist, Bureau of Standards, U. S. Dept. of Commerce, Arsenal, Pittsburgh, Pa.	Assoc. M. M.	April 3, 1907 June 4, 1913
JOHNSON, HENRY STUART. Engr., Loan Fund Comm., City and County of Honolulu; Engr., Constr. and M. of W., Honolulu Rapid Transit & Land Co., Honolulu, Hawaii.		June 4, 1913
LEESON, ROBERT VONARTIEVELDE. Designing and Contr. Engr., The Topeka Bridge & Iron Co., 909 Huntoon St., Topeka, Kans.		May 7, 1913
SCHREIBER, HERMANN VICTOR. Managing Engr., Sellers & Rippey, 1301 Stephen Girard Bldg., Philadelphia, Pa.	Assoc. M. M.	Mar. 1, 1910 June 4, 1913

ASSOCIATE MEMBERS		
BURNHAM, GEORGE EARLE. Res. Engr., Manila R. R., Manila, Philippine Islands	Jun. Assoc. M.	Oct. 1, 1907 June 4, 1913
CORP, HENRY WILLIAM. Res. Engr., Manila R. R., Manila, Philippine Islands	Jun. Assoc. M.	Oct. 1, 1907 June 4, 1913
DAVIS, ARTHUR ALBERT. 112 Prospect Ave., Bethlehem, Pa.		April 2, 1913
DECKER, FRANK WARWICK. Care, Bureau of Lands, Manila, Philippine Islands		June 4, 1913
GREENE, RUSSELL DE COSTA. Knoxville Representative, Knickerbocker Marble Co. of New York City, 1618 West Clinch Ave., Knoxville, Tenn.		June 4, 1913
GRIMES, JAMES EDWARD. Asst. Engr., The San. Dist. of Chicago, 700 Karpen Bldg., Chillicothe, Ill.		Mar. 4, 1913
HINMAN, HERBERT DAVIS. Asst. Engr., Pacific Div., Isthmian Canal Comm., Balboa Terminals, Corozal, Canal Zone, Panama		June 4, 1913
IRVINE, FREDERICK BRICE. Div. Engr., Caribbean Constr. Co., 55 Wall St., New York City		July 2, 1913
MALONY, WALDEN LEROY. Essex, Mont.	Jun. Assoc. M.	Aug. 31, 1909 July 2, 1913
RATHJENS, GEORGE WILLIAM. Supt., Twin City Brick Co., 858 Cherokee Ave., St. Paul, Minn.		June 4, 1913
SHAW, JOHN ARCHIBALD. Care, Dept. of Sewers and Water-Works Constr., Manila, Philippine Islands		July 2, 1913
STOCK, HARRY. Head Designer, W. H. Rosecrans Eng. Co., 4442 Magnolia Ave., Chicago, Ill.		April 2, 1913
WANZER, JAMES OLIN. 1932 Chestnut St., Oakland, Cal.		Mar. 4, 1913

JUNIORS	Date of Membership.
COLLIER, IRA LEONARD. Instrumentman, State Highway Comm., La Center, Wash	May 7, 1913
DAUBENSPECK, HARRY ROSS. Care Morgan Eng. Co., Dayton, Ohio	Mar. 4, 1913
DEISER, NORMAN ARTHUR. Junior Engr., Public Service Comm. for the First District, New York State, 239 New York Ave., Brooklyn, N. Y	June 4, 1913
MAIL, EUGENE FREDERICK. Marion, Ind	Mar. 4, 1913
SEYMOUR, HORATIO, JR. Care, Mrs. Tompkins, Elm Rock Rd., Bronxville, N. Y	April 2, 1913
VELTFORT, THEODORE ERNST. Engr., Dept. of Estimates, Costs, and Reports, Stone & Webster Eng. Corporation, 824 Fulton St., Keokuk, Iowa	Mar. 4, 1913

CHANGES OF ADDRESS

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BELL, ALONZO CLARENCE. 5224 Coliseum St., New Orleans, La.

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BOLTON, CHANNING MOORE. Charlottesville, Va.

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HARDING, ROBERT JOHN. Care, San Antonio Water Supply Co., San Antonio, Tex.

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SCHULTZE, PAUL. Second Deputy Highway Commr., State of New York, Albany, N. Y.

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BELZNER, THEODORE. Insp.-in-Chg., Reinforcing of End Spans, Williamsburgh Bridge, Dept. of Bridges, City of New York, 400 Kent Ave., Brooklyn, N. Y. (Res., 606 West 135th St., New York City.).

BROWN, WILLIAM ALDEN. Gen. Mgr., Aberthaw & Bristol Channel Portland Cement Works, Aberthaw, Glamorgan, Wales.

JUNIORS

BAILEY, PAUL. Res. Engr., Haviland & Tibbetts, 1505 Josephine St., Berkeley, Cal.

BEAN, PAUL JONES. Civ. Engr., U. S. N., U. S. Naval Station, Pearl Harbor, Hawaii.

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BILYEU, CHARLES SMITH. New York Representative, Colby & Christie of Philadelphia, 1 Madison Ave., New York City.

BOWMAN, RALPH MCLANE. Bridge Designer, L. E. & West. R. R., Care, Chf. Engr., Indianapolis, Ind.

COLMAN, JAMES BLAINE THOMAS. 711 South Ingalls St., Ann Arbor, Mich.

HAMMILL, HAROLD BERNARD. Roseville, Cal.

HARRIS, FRANK SAMPSON MASON. 454 Sixty-First St., Oakland, Cal.

HUTCHINS, ROLAND ELLIS. Coll. of Applied Science, Iowa City, Iowa.

KELLERSBERGER, ARNOLD CHARLES. Care, Bowers Southern Dredging Co., Galveston, Tex.

KITTREDGE, FRANK ALVAH. Medford, Ore.

LETTON, HARRY PIKE. San. Engr., U. S. Public Health Service, 1437 Clifton St., N. W., Washington, D. C.

MARSH, EMMETT LINCOLN. Contr. Engr. (Marsh & Gardenier, Inc.), Gold Run, Cal.

MILLER, HAROLD EDMUND. 88 Congress St., St. Albans, Vt.

PAYROW, HARRY GORDON. Res. Engr., Lynn Additional Water Supply, 150 Bellevue Rd., Lynn, Mass.

PETERSON, GARFIELD CHRISTIAN. Glenbeulah, Wis.

PORTER, HARRY FRANKLIN. 5401 Rosalie Ave., Chicago, Ill.

RENNELL, HENRY HURD. Secy. and Treas., Rennell Constr. Co., Inc., 26 Cortlandt St., New York City.

ROBERTS, RICHARD FRANCIS. 138 Centre St., Nutley, N. J.

SLEPPY, KIRBY BALDWIN. With Pacific Elec. Ry., Care, Y. M. C. A., San Bernardino, Cal.

SMITH, HENRY BOUTWELL. 910 Alaska Commercial Bldg., San Francisco, Cal.

STIEVE, WILLIAM MATTHEW. Asst. Engr., Barge Canal, 41 Phelps St., Lyons, N. Y.

JUNIORS (*Continued*)

TURNER, ARTHUR HUBESTY. Second Lieut., U. S. M. C., 188 West River St., Wilkes-Barre, Pa.

WHITMAN, WILLIAM SATTERWHITE. 713½ Woodland St., Nashville, Tenn.

WHITMORE, HAROLD CUSHING. Asst. Engr., Somerset Dam Power Constr. Co., Wilmington, Vt. (Res., 91 Baker St., Lynn, Mass.).

WILEY, RALPH BENJAMIN. Asst. Prof. of San. and Hydr. Eng., Purdue Univ., 1012 Seventh St., West Lafayette, Ind.

WINTON, WALTER FERRELL. Lieut., First U. S. Field Artillery, Honolulu, Hawaii.

DEATHS

BELL, JAMES RICHARD. Elected a Member, September 2d, 1896; died August 8th, 1913.

HINDS, FRANKLIN ALLEN. Elected a Member, May 3d, 1899; died August 23d, 1913.

TORRE, ALBERTO DE LA. Elected an Associate Member, October 3d, 1906; date of death unknown.

Total Membership of the Society, September 4th, 1913, 7 087.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST

(July 31st to September 1st, 1913)

NOTE.—*This list is published for the purpose of placing before the members of this Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS

In the subjoined list of articles, references are given by the number prefixed to each journal in this list:

(1) *Journal,* Assoc. Eng. Soc., Boston, Mass., 30c.
(2) *Proceedings,* Engrs. Club of Phila., Philadelphia, Pa.
(3) *Journal,* Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal,* Western Soc. of Engrs., Chicago, Ill., 50c.
(5) *Transactions,* Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly,* Columbia Univ., New York City, 50c.
(7) *Gesundheits Ingenieur,* München, Germany.
(8) *Stevens Institute Indicator,* Hoboken, N. J., 50c.
(9) *Engineering Magazine,* New York City, 25c.
(10) *Cassier's Magazine,* New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News,* New York City, 15c.
(14) *Engineering Record,* New York City, 10c.
(15) *Railway Age Gazette,* New York City, 15c.
(16) *Engineering and Mining Journal,* New York City, 15c.
(17) *Electric Railway Journal,* New York City, 10c.
(18) *Railway and Engineering Review,* Chicago, Ill., 15c.
(19) *Scientific American Supplement,* New York City, 10c.
(20) *Iron Age,* New York City, 20c.
(21) *Railway Engineer,* London, England, 1s. 2d.
(22) *Iron and Coal Trades Review,* London, England, 6d.
(23) *Railway Gazette,* London, England, 6d.
(24) *American Gas Light Journal,* New York City, 10c.
(25) *Railway Age Gazette,* Mechanical Edition, New York City, 20c.
(26) *Electrical Review,* London, England, 4d.
(27) *Electrical World,* New York City, 10c.
(28) *Journal,* New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal,* Royal Society of Arts, London, England, 6d.
(30) *Annales des Travaux Publics de Belgique,* Brussels, Belgium, 4 fr.
(31) *Annales* de l'Assoc. des Ing. Sortis des Ecoles Spéciales de Gand, Brussels, Belgium, 4 fr.
(32) *Mémoires et Compte Rendu des Travaux,* Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil,* Paris, France, 1 fr.
(34) *Portefeuille Economiques des Machines,* Paris, France.
(35) *Nouvelles Annales de la Construction,* Paris, France.
(36) *Cornell Civil Engineer,* Ithaca, N. Y.
(37) *Revue de Mécanique,* Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways,* Paris, France.
(39) *Technisches Gemeindeblatt,* Berlin, Germany, 0, 70m.
(40) *Zentralblatt der Bauverwaltung,* Berlin, Germany, 60 pfg.
(41) *Elektrotechnische Zeitschrift,* Berlin, Germany.
(42) *Proceedings,* Am. Inst. Elec. Engrs., New York City, $1.
(43) *Annales des Ponts et Chaussées,* Paris, France.
(44) *Journal,* Military Service Institution, Governors Island, New York Harbor, 50c.
(45) *Colliery Engineer,* Scranton, Pa., 25c.
(46) *Scientific American,* New York City, 15c.
(47) *Mechanical Engineer,* Manchester, England, 3d.
(48) *Zeitschrift,* Verein Deutscher Ingenieure, Berlin, Germany, 1, 60m.
(49) *Zeitschrift für Bauwesen,* Berlin, Germany.
(50) *Stahl und Eisen,* Düsseldorf, Germany.
(51) *Deutsche Bauzeitung,* Berlin, Germany.
(52) *Rigasche Industrie-Zeitung,* Riga, Russia, 25 kop.
(53) *Zeitschrift,* Oesterreichischer Ingenieur und Architekten Verein, Vienna, Austria, 70h.
(54) *Transactions,* Am. Soc. C. E., New York City, $12.

(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $6.
(57) *Colliery Guardian*, London, England, 5d.
(58) *Proceedings*, Engrs.' Soc. W. Pa., 803 Fulton Bldg., Pittsburgh, Pa., 50c.
(59) *Proceedings*, American Water-Works Assoc., Troy, N. Y.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *Industrial World*, 59 Ninth St., Pittsburgh, Pa., 10c.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 5c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 6d.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England, 6d.
(69) *Der Eisenbau*, Leipzig, Germany.
(71) *Journal*, Iron and Steel Inst., London, England.
(71*a*) *Carnegie Scholarship Memoirs*, Iron and Steel Inst., London, England.
(72) *American Machinist*, New York City, 15c.
(73) *Electrician*, London, England, 18c.
(74) *Transactions*, Inst. of Min. and Metal., London, England.
(75) *Proceedings*, Inst. of Mech. Engrs., London, England.
(76) *Brick*, Chicago, Ill., 10c.
(77) *Journal*, Inst. Elec. Engrs., London, England, 5s.
(78) *Beton und Eisen*, Vienna, Austria, 1, 50m.
(79) *Forscherarbeiten*, Vienna, Austria.
(80) *Tonindustrie Zeitung*, Berlin, Germany.
(81) *Zeitschrift für Architektur und Ingenieurwesen*, Wiesbaden, Germany.
(82) *Mining and Engineering World*, Chicago, Ill., 10c.
(83) *Gas Age*, New York City, 15c.
(84) *Le Ciment*, Paris, France.
(85) *Proceedings*, Am. Ry. Eng. Assoc., Chicago, Ill.
(86) *Engineering-Contracting*, Chicago, Ill., 10c.
(87) *Railway Engineering and Maintenance of Way*, Chicago, Ill., 10c.
(88) *Bulletin* of the International Ry. Congress Assoc., Brussels, Belgium.
(89) *Proceedings*, Am. Soc. for Testing Materials, Philadelphia, Pa., $5.
(90) *Transactions*, Inst. of Naval Archts., London, England.
(91) *Transactions*, Soc. Naval Archts. and Marine Engrs., New York City.
(92) *Bulletin*, Soc. d'Encouragement pour l'Industrie Nationale, Paris, France.
(93) *Revue de Métallurgie*, Paris, France, 4 fr. 50.
(94) *The Boiler Maker*, New York City, 10c.
(95) *International Marine Engineering*, New York City, 20c.
(96) *Canadian Engineer*, Toronto, Ont., Canada, 10c.
(98) *Journal*, Engrs. Soc. Pa., Harrisburg, Pa., 30c.
(99) *Proceedings*, Am. Soc. of Municipal Improvements, New York City, $2.
(100) *Professional Memoirs*, Corps of Engrs., U. S. A., Washington, D. C., 50c.
(101) *Metal Worker*, New York City, 10c.
(102) *Organ für die Fortschritte des Eisenbahnwesens*, Wiesbaden, Germany.
(103) *Mining and Scientific Press*, San Francisco, Cal., 10c.
(104) *The Surveyor and Municipal and County Engineer*, London, England, 6d.
(105) *Metallurgical and Chemical Engineering*, New York City, 25c.
(106) *Transactions*, Inst. of Min. Engrs., London, England, 6s.
(107) *Schweizerische Bauzeitung*, Zürich, Switzerland.
(108) *Southern Machinery*, Atlanta, Ga., 10c.

LIST OF ARTICLES

Bridges.

Report of Committee (Am. Ry. Eng. Soc.) on Wooden Bridges and Trestles.* (85) Vol. 14.

Practice of Various Railways as to Guard-Rails. (85) Vol. 14.

Descriptions and Photographs Showing Results of Tests Made by the Michigan Central Railroad in 1892 on the Value of Guard Rails on Bridges.* (85) Vol. 14.

Fire Protection on Wooden Bridges and Trestles.* (85) Vol. 14.

Tests of Long-Leaf Pine Bridge Timbers, Atchison, Topeka & Santa Fé Railway System.* H. B. MacFarland. (85) Vol. 14.

Bridges over Navigable Rivers, Some Practical Considerations. C. E. Smith. (85) Vol. 14.

The London and South Western and Metropolitan District Railways' Widening Between Acton Lane and Galena Road.* Eric Alexander Ogilvie. (63) Vol. 192.

*Illustrated.

Bridges—(Continued).

Bridging-Operations Conducted under Military Conditions.* Crofton Edward Pym Sankey. (63) Vol. 192.
Some Experiments on Highway Bridges under Moving Loads.* F. O. Dufour. (4) June.
The Latest Bridge Design for Sydney Harbor, N. S. W.; the Third Largest Span in the World. (13) July 31.
The Design of a Reinforced Concrete Abutment. H. R. Mackenzie. (96) July 31.
Independence Boulevard Bridge, B. & O. C. T. R. R.* A. M. Wolf. (67) Aug.
Mississippi River Bridge at St. Paul, C. G. W. R. R.* (87) Aug.
Concrete Practice No. 9, Missouri Pacific Ry.* A. M. Wolf. (87) Aug.
Nelson Street Viaduct, Atlanta, Ga.* (60) Aug.
Pivot Pier of Chelsea Bridge North, Hollow Concrete Shaft and Foundations Built in Submerged Basket Crib.* (14) Aug. 2.
The Canadian Pacific Railway Bridge over the St. Lawrence River at Lachine.* W. P. Murray. (96) Aug. 7.
Gunpowder and Bush River Bridges.* (14) Aug. 9.
Girder Bridge Encased in Concrete over Prison Point St., East Cambridge, Mass.* (86) Aug. 13.
A Long-Span Double-Deck Bascule Drawbridge.* (13) Aug. 14.
Design and Graphic Method for Calculating a Steel Truss.* Leonard Goodday. (96) Aug. 14.
Lengthy Concrete Slab Bridges, P. B. & W. R. R.* (18) Aug. 16.
Replacing Cedar River Bridge.* (14) Aug. 16.
The Georgia-Harris Viaduct, Vancouver, B. C.* (13) Aug. 21.
Foundation Work on C. P. R. Bridge at Mud Lake, Ontario.* (96) Aug. 21.
The Boucanne River Viaduct.* P. L. Pratley, Assoc. M. Inst. C. E. (96) Aug. 21.
The Mansurah Bridge over the Nile.* (23) Aug. 22.
A 150-Foot Archbridge with Suspended Roadway in Reinforced Concrete.* V. J. Elmont, A. M. Can. Soc. C. E. (96) Aug. 28.
Construction of New Quebec Bridge Piers.* H. P. Borden. (15) Aug. 29.
Highway Bridge Specifications, Requirements for Fabrication of Steel Superstructures Outlined by U. S. Office of Public Roads. (14) Aug. 30.
Field Girder Bridges.* G. E. Smith. (From *Royal Engineers' Journal.*) (100) Sept.
Some Experiments in the Use of Bamboo for Hasty Bridge Construction.* P. S. Bond, M. Am. Soc. C. E. (100) Sept.
Déterminations Graphique des Déformations élastiques des Arcs Fléchis. F. Keelhof. (31) Pt. 2.
Les Nouveaux Ponts sur l'Escaut à Tournai.* T. Seyrig. (30) June.
Les Nouveaux Ponts de Selzaete sur le Canal de Gand à Terneuzen.* T. Seyrig. (30) Aug.
Le Pont de Sewickley, sur l'Ohio (Etats-Unis).* Alfred Jacobson. (33) Aug. 2.
Neubau der Viktoria-Brücke in Bromberg. A. Köhler und V. Lewe. (51) Serial beginning Sup. No. 15.
Visintinibrücke über den Chemnitzfluss.* (80) July 12.
Die Aare-Brücke bei Aarburg.* Zehnder. (107) July 26.
Die Statische Berechnung der Brücken in Gleiskrümmungen.* Siegmund Schwätzer. (69) Aug.
Wettbewerb Bismarckbrücke Saarbrücken.* A. Kleinlogel. (78) Serial beginning Aug. 6.
Vom Zweiten Wettbewerb für einen Entwurf zu einer Strassenbrücke über den Rhein in Cöln.* A. Rohn. (107) Aug. 9; (48) July 12.

Electrical.

On Phase-Advancing (Electric Power).* Gisbert Kapp. (77) July.
The Use of the Electrostatic Method for the Measurement of Power.* C. C. Paterson, E. H. Rayner, and A. Kinnes. (77) July.
Practical Application of Telephone Transmission Calculations.* A. J. Aldridge. (77) July.
Some Oscillograms of Condenser Discharges, and a Simple Theory of Coupled Oscillatory Circuits.* J. A. Fleming. (Abstract of paper read before the Physical Soc.) (73) July 25.
The Influence of Cable Inductance Upon Duplex Balances.* Geo. Wald. (73) July 25.
The System A Onde Unique of the Société Francaise Radio-Electrique.* G. W. O. Howe. (73) July 25.
Electricity Extensions at Burton-upon-Trent.* (26) July 25.
The Development of the Talking Machine. Emile Berliner. (3) Aug.
Electricity Developments in West Hartlepool, the Corporation Waste Heat Generating Station.* (26) Aug. 1.
The Use of the Alternate-Current Potentiometer for Measurements on Telegraph and Telephone Circuits.* C. V. Drysdale. (73) Aug. 1.
Trinidad Government Wireless Station.* (73) Aug. 1.
Centrally-Hung Gas Lamps for Lighting Fleet Street, London.* (73) Aug. 1.

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Electric Arc Welding.* (18) Aug. 2.
Graphical Statics Applied to Transmission-Line Calculations.* Alfred Still. (27) Aug. 2.
150 000 Volt Air-Break Switches for Southern Sierras Transmission System.* (27) Aug. 2.
Power from the Mississippi River.* (64) Aug. 5.
The Electric Arc as a Standard of Light.* J. F. Forrest. (73) Aug. 8.
Hydroelectric Plant on White Salmon River.* (27) Aug. 9.
Distribution Line Records.* H. A. Holmes. (27) Serial beginning Aug. 9.
60 000-Volt Steel-Tower Line Construction in Southern California.* Harry W. Dennis. (27) Aug. 9.
Design of an 1 180-Ft. Transmission-Line Span.* K. Nogami. (27) Aug. 9.
Blasting Method of Excavating Holes for Setting Poles (Telephone).* (From *Du Pont Magazine.*) (86) Aug. 13.
A New Loading Rheostat.* H. H. Broughton. (73) Aug. 15.
On a Dynamo for Maintaining Electrical Vibrations of High Frequency, with Some Notes on the Transmission of Waves in Wireless Telegraphy. Oliver Lodge. (Abstract from the *Philosophical Magazine.*) (73) Aug. 15.
Reinforced Concrete Telegraph Poles. (From *Portland Cement.*) (15) Aug. 15.
Formulas for Capacity of Single-Phase Transmission Lines and Cables.* C. A. Pierce and F. J. Adams. (27) Aug. 16.
Profitable Station in a Town of 3 500 Inhabitants.* (27) Aug. 16.
Methods Employed in Making the Ford Magneto.* Fred H. Colvin. (72) Aug. 21.
A Case of Gaseous Explosion Caused by the Electric Heating of Bitumen in Cable Troughs.* W. M. Thornton and J. A. Smythe. (73) Aug. 22.
Automatic Pressure Regulators.* R. L. Morrison. (73) Serial beginning Aug. 22.
On the Temperature Rise and Deterioration of the Covering Material of Wire by the Carrying Current.* G. T. Hirobe. (Abstract of Report of the Electrotechnical Laboratory, Tokio, Japan.) (73) Aug. 22.
A Study in Depreciation. Louis Bell. (27) Aug. 23.
Combination Railway, Electric and Ice-Making Plant; Newport News & Old Point Railway & Electric Company at Hampton, Va.* A. R. Smith. (27) Aug. 23.
Combination Railway and Lighting System, Description of the Gorge Steam Station of the Northern Ohio Traction & Light Company of Akron, Ohio, at Cuyahoga Falls.* J. C. Lathrop. (27) Aug. 30.
New Power Station of Northern Ohio Traction & Light Company.* (17) Aug. 30.
The Gulf of Georgia Submarine Telephone Cable.* E. P. La Belle and L. P. Crim. (42) Sept.
Effect of Ice Loading on Transmission Lines.* V. H. Greisser. (42) Sept.
Logging by Electricity. E. J. Barry. (42) Sept.
Einphasenmotor mit zur Hauptachse Neutraler Kurzschluss-und Anlaufachse.* A. Heyland. (41) July 24.
Funkentelegraphische Zeitsignalempfänger.* H. Thurn. (41) July 24.
Dielektrische Messungen an Kabeln. M. Klein. (41) Serial beginning July 24.
Die magnetischen Eigenschaften der Legierungen. G. Goldberg. (41) July 31.
Amperestundenzähler für Wechselstrom.* J. Busch. (41) July 31.
Relativ-synchrone Regulierbetriebe.* F. W. Meyer. (41) Serial beginning Aug. 7.
Ueber Verbesserung des Leistungsfaktor.* Gisbert Kapp. (41) Aug. 14.
Beitrag zur Analyse periodischer Kurven.* S. Silbermann. (41) Aug. 14.
Ein neues Spezialmessinstrument für Fehlerortsbestimmungen an Kabeln.* Rich. Randhagen. (41) Aug. 21.
Ueber den Formfaktor der Spannungskurve am Epsteinschen Apparat.* Friedrich Goltze. (41) Aug. 21.

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Oil Fuel in the Royal Navy. (12) July 25.
The Wallsend-Howden System of Oil-Burning in Marine Boilers. (11) July 25.
The Design of Ship-Ventilator Cowls.* G. A. Bisset. (72) July 31.
The Electrical Equipment of a Modern Battleship.* H. A. Horner. (3) Aug.
Propelling Machinery for Collier *Jupiter.** William L. R. Emmet. (95) Aug.
Rebuilding a Double Bottom Under Engines.* Enrico Benvenuti. (95) Aug.
New Steamers for Central Vermont Railway.* (95) Aug.
Brighton Railway Company's New Turbine Steamer for the Newhaven-Dieppe Service.* (23) Aug. 1.
The New Spanish Battleships. (11) Aug. 8.
How the Gyroscope Controls Ships' Rolling.* R. D. Gatewood. (From *Naval Constructor.*) (72) Aug. 14.
The French Destroyer, *Commandant Riviere.** (12) Aug. 15.
The Föttinger Transmitter.* (11) Aug. 15.
The Babcock and Wilcox Boat-Lowering Gear.* (11) Aug. 15.
Watkins's Rotary-Spud Dredger.* (11) Aug. 15.
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Old Dominion Line's Freight Steamer *Tyler*.* (95) Sept.
Single Screw Molasses Tank Steamer *Amolco*.* (95) Sept.
Ship Construction Treated from a Structural Engineering Standpoint.* James E. Steele. (95) Sept.
Redressement de l'Escaut en aval d'Anvers, la Question du Canal-Bassin. C.-J. Van Mierlo. (31) Pt. 2.
Escarbilleurs Hydrauliques pour Navires, Système Stone.* (33) July 5.
Le Cuirassé-Croiseur Japonais *Kongo*.* M. Gouriet. (33) July 19.
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La Nouvelle Forme de Radoub *Gladstone* du Port de Liverpool.* (33) Aug. 16.
Neues Schiffahrtsmaterial für die Rhone.* Rud. Schätti. (107) Aug. 16.

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On the Production of Sound Steel by Lateral Compression of the Ingot Whilst its Centre is Liquid.* Benjamin Talbot. (71) Vol. 87.
On a New Form of Electrically-Driven Two-High Continuous-Running Reversing Mill. Andrew Lamberton. (71) Vol. 87.
Rolling-Mill Practice in the United States. J. Puppe. (71) Vol. 87.
An Investigation of Liquid Contraction in Cast Iron.* George Hailstone. (71*a*) Vol. 5.
The Development of the Drill Test as a Means of Ascertaining the Machining Properties of Iron and Other Metals and for the Investigation of Tool Steels.* A. Kessner. (71*a*) Vol. 5.
The Generation and Distribution of Producer-Gas in South Staffordshire.* Herbert Alfred Humphrey. (63) Vol. 192.
A Method of Designing Cams.* Frederick Grover, Assoc. M. Inst. C. E. (63) Vol. 192.
The Turbo-Blower and Turbo-Compressor.* George Ingram. (63) Vol. 192.
Refractories for the Modern Boiler Plant.* Kenneth Seaver. (58) July.
The Relation of Flue Ventilation to Heating Efficiency in Gas-Fires. W. J. A. Butterfield, Assoc. Inst. C. E. (66) Serial beginning July 22.
Oxide of Iron Purification in Sulphate of Ammonia Works.* (66) July 22.
Direct Recovery of Tar and Ammonia from Coke-Oven Gas by the Still Process.* F. Korten. (From *Glückauf*.) (57) July 25.
Numerical and Graphical Methods in Designing Involute Spur Gears.* A. Schien. (From *General Electric Review*.) (47) July 25.
A Model Gas-Engine Plant in Japan.* (26) July 25.
The Works of Messrs. W. H. Allen, Son and Co., Limited. (11) July 25.
Commercial Motor Vehicle Exhibition, Olympia.* (12) Serial beginning July 25; (11) July 25.
Air Filtration, Cooling and Ventilation of Electrical Machinery. J. Christie. (Paper read before the Municipal Elec. Assoc.) (22) July 25.
Coal-Dust Collecting Plant at Burslem.* (22) July 25.
New Electrically-Driven Rolling Mill Plant of the Steel Company of Canada, Limited.* (22) July 25.
Purification of Blast-Furnace Gases. M. Camille Herwegh. (Paper read before the Société Industrielle de l'Est.) (22) July 25.
Typical Specifications for Steel Castings.* Edwin F. Cone. (20) July 31.
Massive Norton Roll Grinding Machine.* (20) July 31.
The Rod and Merchant Mills of the Dominion Iron and Steel Company, Limited.* (96) July 31.
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Testing Oil Stones for Cutting and Wearing Qualities. (From *Grits and Grinds*.) (108) Aug.
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Fighting the Smoke Nuisance. Harry McNutt. (60) Aug.
Motor Trucks in Municipal Contracting.* H. W. Perry. (60) Aug.
Oil as a Supplementary Fuel in Steam Power-Plants. Reginald Trautschold. (9) Aug.
Recovery of By-Products in the Modern By-Product Coke Oven Plant.* C. A. Meissner. (Paper read before the Am. Iron and Steel Inst.) (105) Aug.
Efficiency Valuation of Fuels.* W. F. Elwood. (45) Aug.
Control of Dust in Portland Cement Manufacture by the Cottrell Precipitation Processes.* Walter A. Schmidt. (67) Aug.
The New Cement Plant at Spokane, Washington, New Methods of Handling Raw Materials, Reducing Dust Troubles and Gravity Loading.* E. W. Miller. (67) Aug.
Methods for Testing Coal Tar.* S. R. Church. (From *Journal of Industrial and Engineering Chemistry*.) (83) Aug. 1.
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Refractory Materials and Temperature Tests. J. W. Mellor. (66) Aug. 5.
High-Pressure Gas Lighting in British Shops.* I. W. Chubb. (72) Aug. 7.
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Fuel for Heavy-Oil Engines. Irving C. Allen. (Abstract of *Bulletin*, U. S. Bureau of Mines.) (96) Aug. 7.
The Development of the Revolving-Grate Gas Producer. (22) Aug. 8.
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The Use of Motor Vehicles by Gas Companies. H. R. Cook, Jr. (Paper read before the Wis. Gas Assoc.) (24) Aug. 11; (83) Aug. 15.
Burners for Oil Fuel.* R. T. Strohm. (27) Serial beginning Aug. 16.
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Purchasers' Tests of Crude Fuel Oil.* W. B. Perkins. (64) Aug. 19.
Mechanical Handling of Materials.* Reginald Trautschold. (96) Aug. 21.
Machining Pulleys and Bearings.* (72) Aug. 21.
Features of American Core Room Practice, a Comparison of Methods in French and American Foundries. Henry Marquette Lane. (Paper read before the Am. Foundrymen's Assoc.) (20) Aug. 21.
The Laboratories of the Modern Factory, Chemical, Physical and Metallographic Apparatus and Investigations of the Studebaker Corporation, Detroit, Mich.* E. F. Lake. (20) Aug. 21.
Axial Thrust in Turbine Pumps, and the Methods of Balancing Same.* A. E. L. Chorlton and L. W. Weil. (11) Aug. 22.
The Adaptibility of Semi-Steel Mixtures. R. Hastings Probert. (Paper read before the Ohio Soc. of Mech., Elec and Steam Engrs.) (47) Aug. 22.
The Steam Friction of Turbine-Wheels.* William Kerr. (Paper read before the Scientific Soc.) (11) Aug. 22; (12) Aug. 22.
Modern Gas Producers and Coal Economy in Melting and Heating Furnaces.* John A. Smeeton. (22) Aug. 22.
Liquid Natural Gas for Industrial Purposes.* Walter O. Snelling. (62) Aug. 25.
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Tests on Small Gasoline Engines. F. M. and E. A. White. (64) Aug. 26.
Development of Motor Omnibus Transportation in London. E. S. Sharpnell-Smith. (Abstract of paper read before the Inter. Road Congress.) (86) Aug. 27.
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The Design of Chains and Chain Wheels.* Henry E. Hayward. (72) Serial beginning Aug. 28.
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Turbine Pelton de 6 000 Chevaux.* Maurice Gariel. (34) Aug.
Nouvelles Machines Frigorifiques.* Norbert Lallié. (34) Aug.
Les Appareils de Fusion pour l'Acier Moulé. J. Lambot. (93) Aug.
Etude des Nouveaux Systèmes de Condensation Goudronneuse du Gaz de Houille et de Production du Sulfate d'Ammoniaque.* Charles Berthelot. (93) Aug.
Etude Résumée sur les Sables de Fonderie et leur Traitement. A. L. Curtis. (93) Aug.
Le Travail et l'Installation des Fonderies ainsi que des Usines en Général en Amérique. Brasseur. (93) Aug.
Zeichnerische Diagrammermittlung für Fördermaschinen mit Antrieb durch Reihenschlussmotoren (Fördermaschinen mit Treibscheibe, zylindrischen und kegeligen Trommeln und Bobinen).* Gregor Trefler und Fritz Nettel. (48) Serial beginning June 14.
Die Seilschwebebahn für Personenbeförderung in Rio de Janeiro, erbaut von J. Pohlig A.-G. in Köln.* Albert Pietrkowski. (48) June 14.
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Der Turbinenpumpenbau von C. H. Jaeger & Co.* H. Mitter. (48) June 28.
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Der Dampfverbrauch der Abdampf-und Zweidruckturbinen bei den verschiedenen Betriebsverhältnissen.* K. Röder. (48) July 5.
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Die experimentelle Bestimmung des Ungleichförmigkeitsgrades.* Wilhelm Riehm. (48) July 12.
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Die Ausnutzung der Rauchgase von Drehrohröfen zur Dampferzeugung. Otto Schott. (80) July 12.
Trommelmühlen verglichen mit anderen Mahlmaschinen.* Gerhard Zeyen. (80) July 17.
Kohlen-und Aschesilo in Eisenbeton für Fa. Rudolf Sack, Leipzig-Plagwitz.* (78) July 19.
Ueber Nebenproduktengewinnung aus Generatorgas (Ein Beitrag zur Wirtschaftlichkeitsfrage). R. Schulz. (50) July 24.
Die spezifischen Eigenschaften und Unterschiede der festen und flüssigen Brennstoffe und ihre technische Bedeutung.* Aufhäuser. (50) July 24.
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The Estimation of Oxygen in Iron and Steel. J. A. Pickard. (71*a*) Vol. 5.
Method of Producing Sound Ingots. W. C. Cushing. (85) Vol. 14.
The Economy of Dry Blast. Josef von Ehrenwerth. (71) Vol. 87.
Influence of Sulphur on the Stability of Iron Carbide in the Presence of Silicon.* W. H. Hatfield. (71) Vol. 87.
Some Fundamental Faults of Present-Day Furnaces and Their Remedies.* Alleyne Reynolds. (71) Vol. 87.
A New Method for the Accurate Determination of Phosphorus. C. H. Ridsdale and N. D. Ridsdale. (71) Vol. 87.
The Critical Ranges of Pure Iron with Special Reference to the A2 Inversion.* H. C. H. Carpenter. (71) Vol. 87.
The Influence of the Metalloids on the Properties of Cast Iron. H. I. Coe. (71) Vol. 87.
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Slow-Speed Chilean Mill Data. Erich J. Schrader. (103) July 26.
The Precipitation of Gold by Manganous Salts. A. D. Brokaw. (Paper read before the Am. Chemical Soc.) (103) July 26.
The Temperature of Certain Operations in the Metallurgy of Copper and Lead.* G. Howell Clevenger. (105) Aug.
Two Arizona Cyanide Mills.* Herbert A. Megraw. (16) Aug. 2.

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Operation of the West End Mill, Tonopah. Jay A. Carpenter. (103) Aug. 2.
Blast Quantity and Pressure in Cupola Working.* F. J. Cook. (Paper read before the British Foundrymen's Assoc.) (20) Aug. 7.
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Electrostatic Separation of Barstow Concentrate.* C. R. Wilfley. (16) Aug. 9.
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New Smeltery of United Verde Copper Company.* Richard H. Vail. (16) Serial beginning Aug. 16.
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Rapid Determination of Nickel in Steel. Percy S. Brown. (From *Metal Industry.*) (20) Aug. 21.
The Coleraine Iron Ore Washing Plant.* John Uno Sebenius. (Abstract of paper read before the Lake Superior Min. Inst.) (20) Aug. 28.
The Argo Cyanide Mill, Idaho Springs, Colo.* Stephen L. Goodale. (16) Aug. 30.
La Soudure Electrique par électrodes métalliques, procédé Strohmenger.* L. Clerc. (34) Aug.
Technologische Schlüsse aus der Kristallographie der Metalle.* W. v. Moellendorff und J. Czochralski. (48) Serial beginning June 14.
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Field Girder Bridges.* G. E. Smith. (From *Royal Engineers' Journal.*) (100) Sept.
Some Experiments in the Use of Bamboo for Hasty Bridge Construction.* P. S. Bond, M. Am. Soc. C. E. (100) Sept.

Mining.

Small Coal and Dust: Its Production, Prevention, Treatment, and Utilization, with Special Reference to Dry Mines.* J. Drummond Paton. (Paper read before the Manchester Geol. and Min. Soc.) (106) Vol. 45, Pt. 3.
Notes on the Geology of Shansi and the Coal Industry in Northern China.* Noah T. Williams. (Paper read before the Manchester Geol. and Min. Soc.) (106) Vol. 45, Pt. 3.
Notes on the Effect of Temperature in Mines in Great Britain. John Cadman. (Paper read before the Midland Counties Institution of Engrs., and the Midland Inst. of Min., Civ. and Mech. Engrs.) (106) Vol. 45, Pt. 3.
Reinforced Concrete in Mines.* S. M. Dixon. (Paper read before the South Staffordshire and Warwickshire Inst. of Min. Engrs.) (106) Vol. 45, Pt. 3.
A Record of the Origin of the Principle of Stone-Dusting for the Prevention of Colliery Explosions. W. E. Garforth. (106) Vol. 45, Pt. 4.
The Reopening of Norton Colliery with Self-Contained Breathing-Apparatus after an Explosion.* J. R. L. Allott. (106) Vol. 45, Pt. 4.
The Use of High-Tension Continuous Current on the Thury System in Mines. S. F. Walker. (77) July.
New Screening Plant at Whitwood Colliery.* (22) July 25.
The Coalfields of India.* V. Ball. (Abstract from *Memoirs* of the Geol. Survey of India, revised by R. R. Simpson.) (22) July 25.
The German West African Diamond Fields. (68) July 26.
The Amakie Sapphire Fields of Queensland. Lionel C. Ball. (From *Queensland Mining Journal.*) (103) July 26.
A Cost and Time Study of Big Blast Hole Drilling. R. R. Sanderson. (67) Serial beginning Aug.
Fire Protection of Mines. James Taylor. (Paper read before the Mining Conference, Univ. of Illinois.) (45) Aug.
Four-Decked Cage at St. Michael.* (45) Aug.
Working an Inclined Coal Bed.* George Watkin Evans. (45) Aug.
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Water Purifier for Locomotive Boilers.* Cornelius Pecz. (88) July.
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Wooden Sleepers or Iron Sleepers. Rectanus. (From *Zeitung* des Vereins deutscher Eisenbahn Verwaltungen.) (88) July.
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AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

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Vol. XXXIX. SEPTEMBER, 1913. No. 7.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

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MEASUREMENT OF THE FLOW OF STREAMS BY APPROVED FORMS OF WEIRS WITH NEW FORMULAS AND DIAGRAMS.

Details and Summaries of the Results of Experiments by Francis, Bazin, Fteley and Stearns, and at the Hydraulic Laroratories of Cornell University and the University of Utah.

By Richard R. Lyman, Assoc. M. Am. Soc. C. E.

To be Presented November 19th, 1913.

It is probable that in the near future practically every farmer in the West will be required to place a weir at the head of his farm for the purpose of measuring the irrigating water he uses.

Wherever water is used for any purpose, its measurement, in a more or less accurate way, is important; but in the middle and western parts of the United States, and wherever else practically all agricultural interests depend on water for purposes of irrigation, this problem is of the utmost importance. Water has already become so valuable in these sections that laws have been enacted requiring that weirs be placed in every important stream.

If only the matters herein discussed are considered, the title given to this paper is a broader one than it deserves; but the method of

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

handling the weir data is such that, in the writer's opinion, it may wisely be applied to every phase of the weir problem.

In the West the measurement of water should be made in the most accurate manner practicable. From the point of view of the engineer and the investigator, the method of calculating the discharge over a weir should be the simplest that can be found; in other words, it should give the most accurate results with the smallest amount of work.

It is the purpose of this paper to present a more accurate method of measuring water than those generally used, and to give formulas and diagrams for determining the discharge over the weirs recommended. These, the writer believes, are simpler and easier of application than any weir formulas heretofore devised.

Soon after the publication of the handy and thoroughly practical "Diagrams of Mean Velocity of Uniform Motion of Water in Open Channels,"* by Professor I. P. Church, Assoc. Am. Soc. C. E., of Cornell University, the writer conceived the idea of preparing a similar set of diagrams for determining the quantity of water flowing over weirs under various conditions. The results of his efforts are presented as a part of this paper.

The use of the various diagrams will be explained first; afterward, the data on which they are based will be set forth, and then the methods used in getting the results.

I.—Flow of Water Over Weirs.

A.—Advantages in Practice of Using Weirs Without End Contractions.

First.—The water above the weir without end contractions has a greater velocity for the same quantity of flow than above weirs with end contractions, therefore less sediment will be deposited above the former than above the latter. This fact is important, as the accuracy of the measurements obtained depends largely on having the cross-section of the stream above the weir constant, especially if the height of the crest of the weir above the bottom of the channel of approach is comparatively small.

Secondly.—The weir without end contractions will necessarily have to be placed near the down-stream end of a channel made of lumber or some material which will retain a rectangular form. Although this requires a comparatively expensive construction, the weir and the

* Published by John Wiley and Sons, New York.

bulkhead holding it can be removed, thus making it easy to flush and clean the channel. In fact, if a very high degree of accuracy is not required, the bulkhead and metal crest need be put in place only when measurements are actually being taken.

Thirdly.—As the quantity of water flowing over the weir is almost exactly proportional to its length, water may be divided accurately at the same time that it is being measured, by placing one or more vertical dividing blades below the weir and cutting the stream into the desired number of parts having the required proportions. Where end contractions are used, they affect the quantity of discharge per unit of length of weir in such a variable and uncertain way as to make an accurate division of the water as it falls very difficult, if not actually impossible.

Fourthly.—The extensive and accurate information herein given, and used as a basis for the results reached, has been obtained by our greatest hydraulicians. We may have to wait a long time before obtaining a series of experiments on any form of weir which will equal these in thoroughness, extent, or accuracy.

Fifthly.—The simplicity of the correct construction of this weir is a great advantage. The crest is its only sharp edge. It is easier to make the sides plane and vertical than to construct them on a definite slope with sharp edges, as is necessary, for example, in the Cippoletti weir. Almost any farmer, with simple instructions, can construct a weir of this type which will answer well for measuring the water he uses on his land.

Sixthly.—The simplicity of the method of finding accurately the discharge over the weir, by using the diagram herein given, is perhaps not the least of the advantages the weir without end contractions has over others. The method of ascertaining the discharge is so simple that any one who can read the depth of the water on the crest can read the discharge from the diagram; and as the only mathematical operation required is the multiplication of the figure thus obtained by the length of the weir, in feet, the chance of making an error is reduced to a minimum.

It is the writer's opinion that the sharp-crested weir without end contractions can certainly be used to best advantage in all irrigation projects, great and small, of the West, where mountain streams must soon be measured, divided, and re-divided many times before the water

is finally used for producing crops. It will be well, indeed, if some legislation can be enacted soon, or some other action can be taken, which will make this weir a standard for measuring water, just as the House of Representatives of the United States fixed a standard gauge for measuring the thickness of sheet iron and steel.

B.—Application of Results to:

1.—Sharp-Crested Weirs Without End Contractions.

a.—For Heads Within the Limits of the Experiments Performed.—Plate LXXX.—The curves on Plate LXXX, which show the discharges over sharp-crested weirs without end contractions, are based on experiments by Bazin, Fteley and Stearns, Francis, and in the Hydraulic Laboratories of Cornell University and the University of Utah. As this diagram is constructed from the results of all these "classic" experiments, and as it fits the experiments with a high degree of accuracy, the writer feels that its results can be relied on with greater confidence than can those obtained by using any one of the more or less complicated weir formulas which the experimenters themselves have devised, using only their own experiments as a basis.

Although, by use of the analytic expressions or formulas given later, quantities of discharge can be computed containing a greater number of significant figures than can be read from this diagram, and from others herein presented, these easily give results as accurate as warranted by the experimental data on which they are based. See Plate LXXXI.

On Plate LXXX there are three sets of lines, each marked so as to be easily distinguished from the others. One represents the head on the weir, in feet, another the discharge over the weir, in cubic feet per second per foot of length of weir, and the third the height of the crest of the weir above the bottom of the channel of approach.

Example 1.—What volume of water per second will flow over a sharp-crested weir, 5 ft. long, without end contractions, the height of the crest above the bottom of the channel of approach being 2 ft., and the depth of water on the crest (the height of the surface of the water above the crest) being 1.20 ft.?

The line representing a head of 1.20 ft. on Plate LXXX intersects that for a weir of height 2 ft. above the floor of the channel of approach

THE HYDRAULIC LABORATORY OF CORNELL UNIVERSITY.

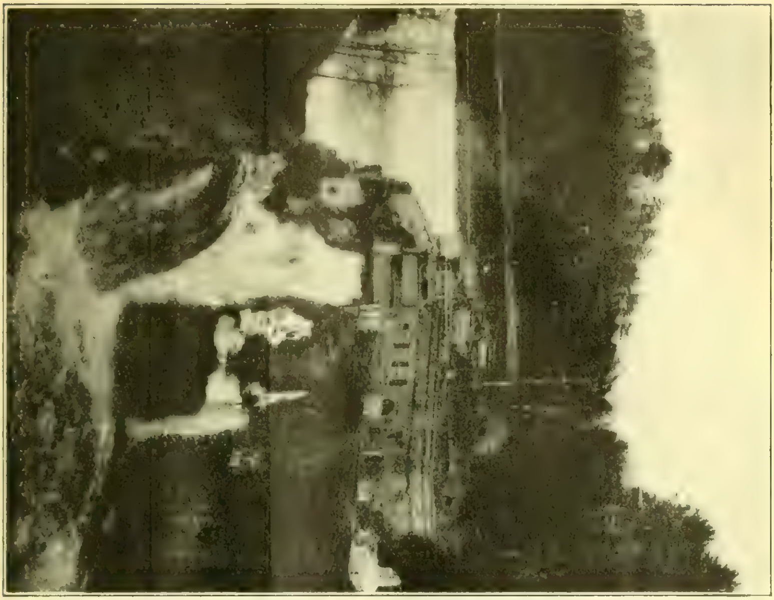


FIG. 1.—DURING THE HIGH-WATER SEASON.

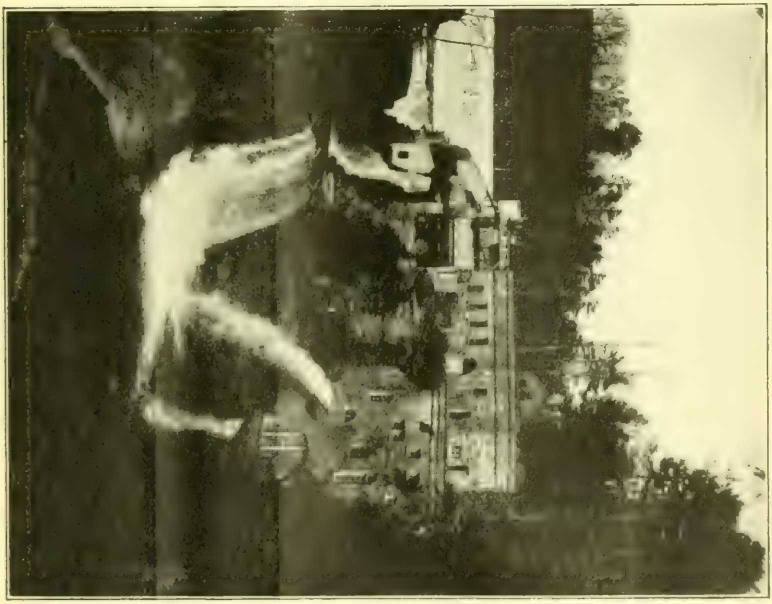
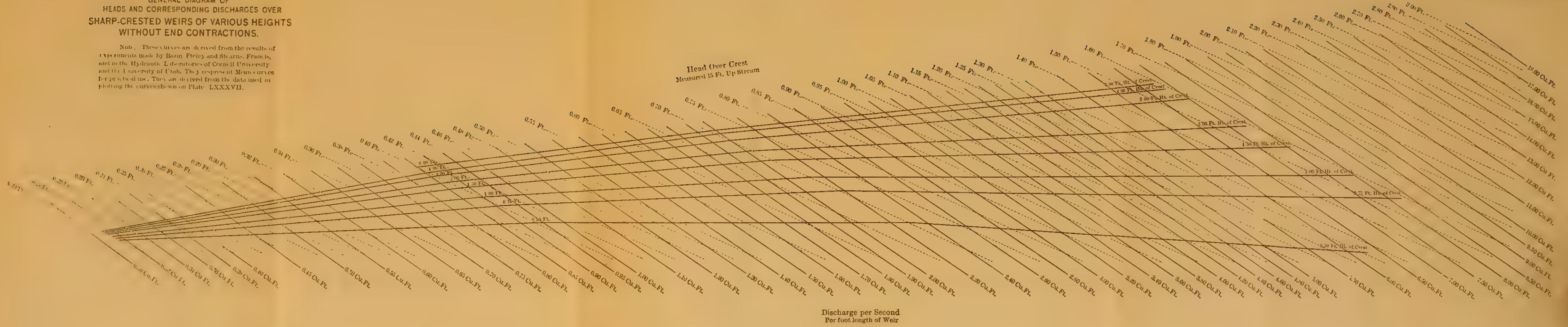


FIG. 2.—DURING THE LOW-WATER SEASON.

GENERAL DIAGRAM OF
HEADS AND CORRESPONDING DISCHARGES OVER
SHARP-CRESTED WEIRS OF VARIOUS HEIGHTS WITHOUT END CONTRACTIONS.

Note. These curves are derived from the results of experiments made by Bazin, Fteley and Stearns, Francis, and in the Hydraulic Laboratories of Cornell University and the University of Utah. They represent Mean curves for practical use. They are derived from the data used in plotting the curves shown on Plate LXXXVII.



at a point slightly more than half way from the line representing a discharge of 4.60 cu. ft. per sec. to that representing a discharge of 4.80 cu. ft. per sec. The discharge per foot of length as read is 4.74 cu. ft. per sec. per ft. of length of weir, or 23.70 cu. ft. per sec. over the weir 5 ft. long.

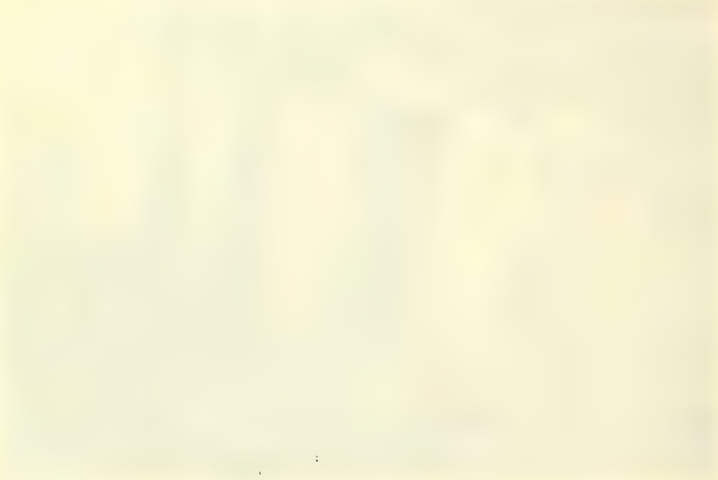
Example 2.—What depth on the crest of a weir without end contractions will a flow of 8 cu. ft. per sec. reach if the weir is 2 ft. long and the height of the crest above the bottom of the channel of approach is 1.5 ft.?

The discharge per foot of length of weir is 4 cu. ft. per sec. The line on Plate LXXX representing this discharge intersects that representing a weir of height 1.5 ft. between the lines representing the heads, 1.05 and 1.10 ft., at a point which shows that the head on the weir is 1.06 ft.

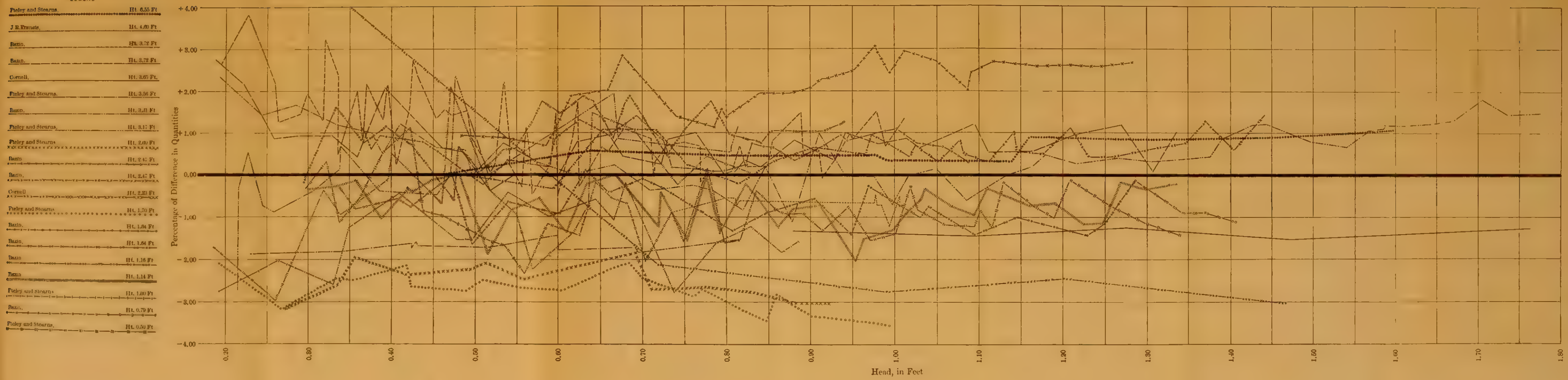
From a blue print of the original Plate LXXX, which is about 50 in. long and 12 in. wide, all the discharges were taken for each and every run made by the original experimenters, and the difference, as a percentage, was computed between the quantities thus obtained and those originally measured. Each reading from the diagram was the average of two independent readings.

These results are shown on Plate LXXXI. Every run in every experiment is plotted. The abscissas represent the heads, in feet; the ordinates represent the quantity differences as percentages. A glance at the diagram shows that nearly all these results are below the + 1% line and above the — 1% line. This means that the diagram gives results in nearly all cases varying less than 1% from the original accurate data. How near the results given by the diagram fit the data obtained by any particular investigator in any series of runs can be seen by following the special line which represents that particular set of runs.

In the upper portion of Plate XCII it can be seen that, even with great care, an error of one-half of 1% in the discharge may be due to imperfections in measuring the head, yet the discharge diagram now being considered gives the accurate results just named, and therefore the assertion was made near the beginning of this paper that these results "can be relied on with greater confidence than can those obtained by using any one of the more or less complicated weir formulas which the experimenters themselves have devised."



DIFFERENCE IN PERCENTAGE BETWEEN THE ACTUAL DISCHARGES MEASURED BY EXPERIMENTERS AND THOSE OBTAINED BY USE OF PLATE LXXX



That the diagrams here given are time-savers will be plain to the reader if he makes the computations which the formulas require in order to determine the quantities of discharge for weirs of the heights shown on Plate LXXXII. If these results are furnished for a series of heads on each of these weirs, the writer will gladly put this additional information on the diagram.

(2).—Broad-Crested Weirs.—Plate LXXXIII.

(*a*).—*Broad-Crested Weirs of One Height, Namely 11.25 Ft., the Height of the Model on Which the Experiments Were Made.*—The curves on Plate LXXXIII, which give the discharge over a series of broad-crested weirs without end contractions, all having the same height, 11.25 ft., are based on a long and careful series of experiments in the hydraulic laboratory of Cornell University. Although the standard weir with which the water was measured, after it had flowed over the model, was not rated by actually catching and measuring the water volumetrically, the computations concerning the discharges measured over it* have been such that the results it gives can be accepted as accurate to within 2 or 3 per cent.†

On Plate LXXXIII also there are three series of lines. One gives the head or depth of water on the crest of the weir, measured 16 ft. up stream from the crest; another, the discharge per foot of length of weir; and the third, the width of the crest, in feet.

For every point on the diagram there is a definite discharge, and also a definite head. To ascertain the discharge for a given head on a weir of known width, find where the line representing the head intersects that representing the width. The discharge represented by this point of intersection is that for the given weir for 1 ft. of length.

It should be noted that, for comparatively low heads, all these broad-crested weirs give practically the same result for the same head.‡ At a particular head or point, however, for each width of crest, the quantity of discharge begins suddenly to increase much faster, in proportion to the head, than it has done before, and the line representing its discharge breaks away from *AA* and extends across the diagram in a

* "Weir Experiments, Coefficients, and Formulas," by Robert E. Horton, Water Supply Paper No. 150, U. S. Geological Survey, p. 39; also G. W. Rafter, "On the Flow of Water Over Dams." *Transactions*, Am. Soc. C. E., Vol. XLIV, p. 397.

† *Loc. cit.*, p. 40.

‡ The line, *AA*, represents this condition.

slanting direction to the line, *BB*, which represents the discharge over weirs with sharp crests. The head shown by the point at which such a line meets *BB* is that at which the sheet jumps over the crest without touching it. For all higher heads the sharp-crest condition obtains.

The condition that exists between the "broad-crest" or "open-channel" line and the "sharp-crest" line is perhaps produced by the tendency of the flowing stream to create a vacuum on top of the broad crest. This will be called the intermediate condition. Three examples of finding the discharge over a weir of width 1.5 ft. will be given: one for the "open-channel" condition, another for the "sharp-crest" condition, and a third for the intermediate condition.

Example 1.—(Open-Channel Condition).—What is the discharge over a weir 1.5 ft. wide and 4 ft. long, where the head on the weir is 0.48 ft.?

The line representing a head of 0.48 ft. intersects that representing a weir of width 1.5 ft. at a point showing a discharge of 0.90 cu. ft. per sec. per ft. of length. The discharge over a weir 4 ft. long is four times this quantity, or 3.60 cu. ft. per sec.

Example 2.—(Sharp-Crest Condition).—What is the discharge over a weir 1.5 ft. wide and 4 ft. long, where the head on the weir is 3.60 ft.?

The line representing a head of 3.60 ft. intersects that representing a weir of width 1.5 ft. at a point showing a discharge of 23.5 cu. ft. per sec. per ft. of length. The discharge over the weir 4 ft. long is four times this quantity, or 94.0 cu. ft. per sec.

Example 3.—(Intermediate Condition).—What is the discharge over a weir 1.5 ft. wide and 4 ft. long, where the head on the weir is 1.40 ft.?

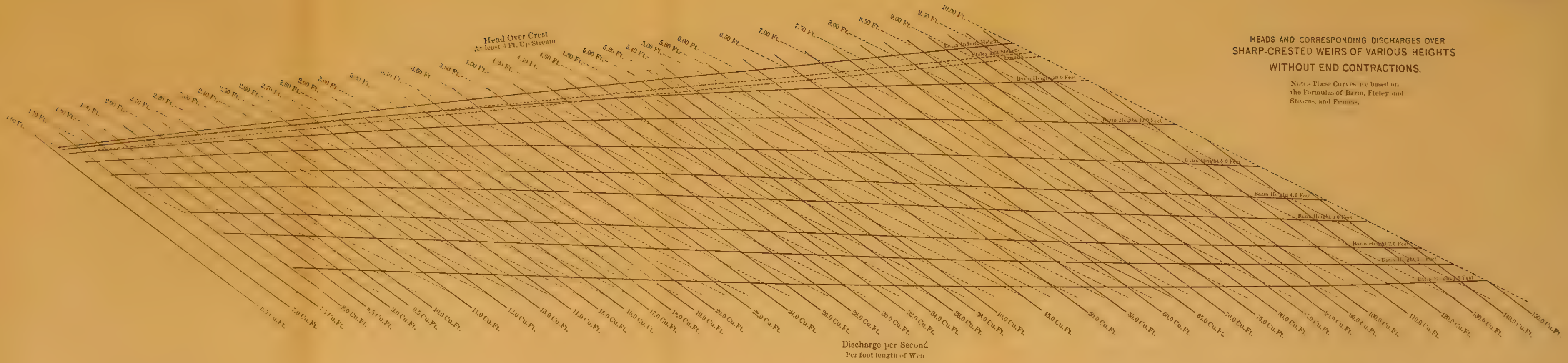
The line representing a head of 1.40 ft. intersects that representing a weir of width 1.5 ft. at a point showing a discharge of 4.93 cu. ft. per sec. per ft. of length. The discharge over the weir 4 ft. long is four times this quantity, or 19.72 cu. ft. per sec.

The dimensions and other details of the models on which these experiments were conducted are shown on Plate XC, and in Figs. 16, 17, and 20 to 27, inclusive.

(*b*).—*Broad-Crested Weirs of Any Height.*—It was at the suggestion of Gardner S. Williams, M. Am. Soc. C. E., that the writer prepared Table 0, showing the coefficients to be applied to the quantities of discharge given by Plate LXXXIII (and applicable only to weirs having the same height as the models on which the experi-

HEADS AND CORRESPONDING DISCHARGES OVER SHARP-CRESTED WEIRS OF VARIOUS HEIGHTS WITHOUT END CONTRACTIONS.

Note.- These Curves are based on the Formulas of Bazin, Fteley and Stearns, and Francis.



ments were made, namely, 11.25 ft.), in order to obtain the discharge over broad-crested weirs of any height.

TABLE 0.—COEFFICIENTS BY WHICH THE QUANTITIES OF DISCHARGE OVER BROAD-CRESTED WEIRS AND IRREGULAR-CRESTED WEIRS OF 11.25 FT. (THE QUANTITIES GIVEN ON PLATES LXXXIII AND LXXXV) ARE TO BE MULTIPLIED IN ORDER TO GIVE THE DISCHARGE OVER WEIRS OF THE HEIGHTS SHOWN IN THE TABLE AND FOR THE HEADS THERE GIVEN. COEFFICIENTS FOR OTHER HEADS AND FOR WEIRS OF OTHER HEIGHTS MAY BE FOUND BY INTERPOLATION.

Head, in feet.	Height of Weir, in Feet.										
	0.5	0.75	1.00	1.50	2.00	3.00	4.00	6.00	10.00	20.00	Infinite.
0.2	1.026	1.023	1.020	1.016	1.013	1.010	1.006	.....	.....	.....	.....
0.3	1.076	1.056	1.042	1.031	1.023	1.018	1.013	.....	.....	.....	.....
0.4	1.107	1.077	1.063	1.041	1.035	1.024	1.018	1.012	.....	.....	.....
0.5	1.137	1.095	1.076	1.052	1.039	1.025	1.018	1.009	.....	.....	.....
0.6	1.160	1.102	1.086	1.053	1.040	1.024	1.014	1.008	.....	.....	.....
0.7	1.175	1.116	1.090	1.059	1.039	1.021	1.011	1.006	.....	.....	.....
0.8	1.217	1.137	1.105	1.073	1.053	1.027	1.015	1.010	.....	.....	.....
0.9	1.237	1.149	1.118	1.079	1.054	1.026	1.016	1.009	.....	.....	.....
1.0	1.265	1.166	1.130	1.088	1.063	1.028	1.016	1.009	.....	.....	.....
1.2	1.311	1.191	1.150	1.104	1.070	1.034	1.016	1.007	.....	.....	.....
1.4	.....	1.216	1.171	1.117	1.083	1.035	1.018	1.011	.....	.....	.....
1.6	.....	.....	1.200	1.137	1.104	1.056	1.037	1.015	1.003	0.992	0.991
1.8	.....	.....	1.213	1.150	1.111	1.063	1.039	1.016	1.001	0.992	0.987
2.0	.....	.....	1.227	1.164	1.122	1.074	1.047	1.020	1.001	0.989	0.984
2.5	.....	.....	1.254	1.189	1.148	1.091	1.061	1.030	1.004	0.989	0.985
3.0	.....	.....	1.274	1.211	1.166	1.103	1.069	1.029	1.006	0.983	0.971
3.5	.....	.....	1.288	1.225	1.180	1.122	1.081	1.040	1.004	0.977	0.968
4.0	.....	.....	1.301	1.243	1.195	1.132	1.092	1.044	1.004	0.974	0.963
4.5	.....	.....	1.315	1.253	1.212	1.147	1.104	1.055	1.009	0.978	0.957
5.0	.....	.....	1.318	1.266	1.220	1.156	1.116	1.060	1.007	0.971	0.950
5.5	.....	.....	1.320	1.270	1.227	1.168	1.118	1.067	1.011	0.972	0.948
6.0	.....	.....	1.321	1.269	1.230	1.171	1.127	1.068	1.009	0.965	0.937
6.5	.....	.....	1.312	1.264	1.224	1.166	1.123	1.068	1.008	0.960	0.926
7.0	.....	.....	1.317	1.270	1.232	1.171	1.127	1.072	1.011	0.961	0.922
7.5	.....	.....	1.314	1.273	1.236	1.177	1.136	1.075	1.013	0.958	0.917
8.0	.....	.....	1.313	1.270	1.233	1.177	1.134	1.078	1.014	0.954	0.911
8.5	.....	.....	1.315	1.270	1.236	1.180	1.136	1.078	1.012	0.951	0.908
9.0	.....	.....	1.311	1.270	1.239	1.187	1.141	1.084	1.013	0.951	0.899
9.5	.....	.....	1.306	1.269	1.238	1.188	1.145	1.084	1.014	0.948	0.901
10.0	.....	.....	1.299	1.264	1.234	1.182	1.143	1.082	1.013	0.944	0.892

These coefficients were obtained by assuming that the effect of the height of the weir in the case of broad crests is the same as in that of sharp crests. The discharges over sharp-crested weirs having the heights given in Table 0 and the heads there indicated, were found from Plates LXXX and LXXXII for sharp-crested weirs. The ratios were then found between the quantities thus obtained and the discharge over a sharp-crested weir of height 11.25 ft. for the corresponding heads. These ratios are the coefficients given in Table 0. Although

the degree of accuracy they give is necessarily uncertain, it is believed that the results found by their use will be the best obtainable until additional reliable data are secured.

(3).—Weirs with Irregular Cross-Sections.—Plates LXXXIV and LXXXV.

(*a*).—*Specific Weirs of Heights Shown.*—Plates LXXXIV and LXXXV show the actual results obtained by experiments on a series of models of irregular cross-sections in the hydraulic laboratory of Cornell University. There is not sufficient similarity in the models used to make a general diagram from the results obtained, which will apply to weirs with any cross-section, or even to those with somewhat similar cross-sections, as was done in the case of the sharp-crested weirs on Plate LXXX or the broad-crested weirs on Plate LXXXIII.

It is believed, however, that from these two diagrams a close estimate can be made of the quantity of water flowing over almost any weir or dam of irregular cross-section. As readings are taken on these plates exactly as they are on Plates LXXX and LXXXIII, no further examples or explanations need be given on this point.

Cross-sections of these models, showing their dimensions and method ot construction are given on these two plates, and in Figs. 17 to 19, and 28 to 45, inclusive. The curves are also marked with the model number, so that the line for any particular form may be easily followed.

(*b*).—*Weirs of Any Height, if Similar to Those Models Shown on Plate LXXXV That Have a Height of 11.25 Ft.*—For the same reason that the coefficients in Table 0 may be applied to the discharge over broad-crested weirs, having a height of 11.25 ft., in order to obtain the discharge over similar weirs of different heights, these same coefficients may be applied to the discharges obtained from Plate LXXXV for the models having a height of 11.25 ft., in order to obtain the discharge over similar models of different heights. The models having a height of 11.25 ft. from which experiments were actually made are the following: XXX, XXXIII, XXXIV, XXXV, XXXVI, XXXVIII, and XXXIX. For further explanation, see "(*b*) Broad-Crested Weirs of Any Height."

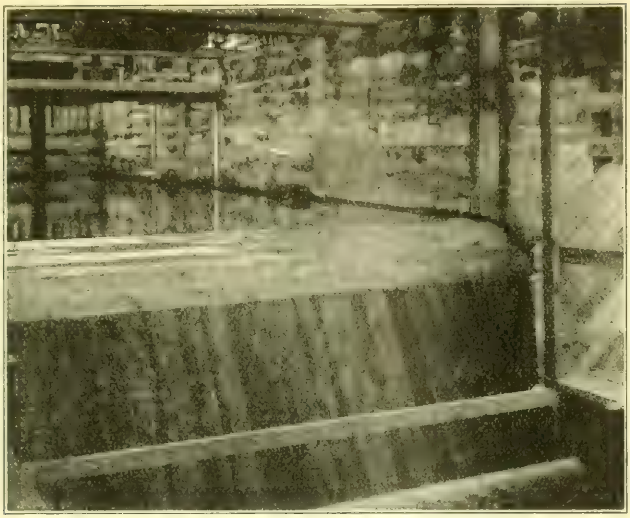


FIG. 5.—MODEL OF CHAMBLY DAM, IN UPPER END OF CANAL, CORNELL HYDRAULIC LABORATORY.

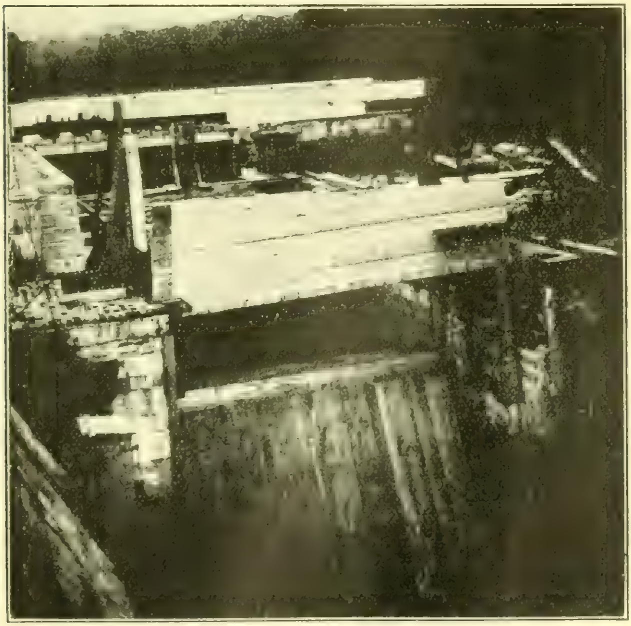


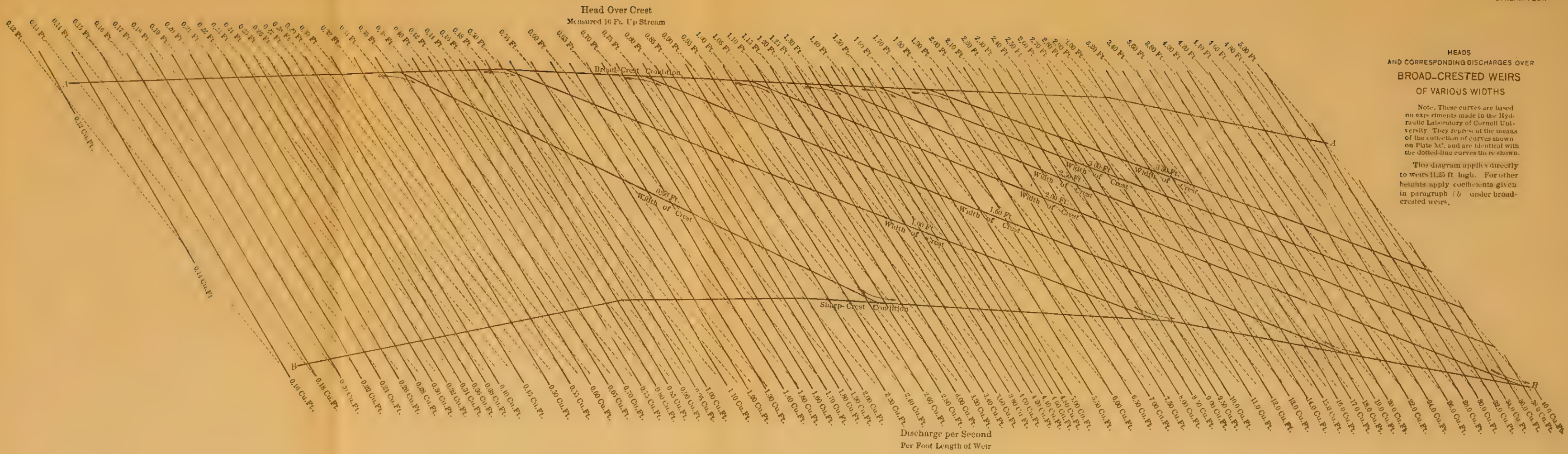
FIG. 6.—MODEL OF PLATTSBURG DAM, IN UPPER END OF CANAL, CORNELL HYDRAULIC LABORATORY.

PLATE LXXXIII.
PAPERS, AM. SOC. C. E.
SEPTEMBER, 1913.
LYMAN ON
WEIR MEASUREMENT OF
STREAM FLOW

HEADS
AND CORRESPONDING DISCHARGES OVER
BROAD-CRESTED WEIRS
OF VARIOUS WIDTHS

Note. These curves are based on experiments made in the Hydraulic Laboratory of Cornell University. They represent the means of the collection of curves shown on Plate XC, and are identical with the dotted-line curves there shown.

This diagram applies directly to weirs 11.25 ft. high. For other heights apply coefficients given in paragraph (b) under broad-crested weirs.



C.—Formulas for Calculating the Discharge Over Weirs.

(1).—The Francis Formula.

The Francis formula for weirs without end contractions is used most generally. It is as follows:

$$Q = 3.33\ H^{\frac{3}{2}}\text{*}$$

in which

Q = discharge, in cubic feet per second per foot of length of weir;

and H = effective head of water on the weir, in feet; its value to be obtained by using the formula:

$$H = (h + h')^{\frac{3}{2}} - h'^{\frac{3}{2}}\dagger$$

in which

h = the measured head, or the vertical distance, in feet, between the horizontal plane containing the crest of the weir and the plane surface of the water in the channel of approach;

and $h' = \frac{V^2}{2g}$, V being the velocity of the water in the channel of approach, and g the acceleration of gravity.

Mr. Francis has pointed out that making this correction for the velocity of approach "will be requisite only when great precision is required." For, he says, in one of his experiments, the water in the channel of approach had a mean velocity of about 1 ft. per sec., and this had the effect of increasing the discharge about 2%, and, in another experiment, the velocity was about 0.5 ft. per sec., and this had the effect of increasing the discharge about 1 per cent. "These examples," writes Mr. Francis, "will enable the operator to judge, in each case, of the necessity of going through the troublesome calculation for correcting the depth on the weir."‡

(2).—Formula of Fteley and Stearns.

For weirs without end contractions, Messrs. Fteley and Stearns, from their experiments, deduced the following formula:

$$Q = 3.31\ (h + 1.5\ h')^{\frac{3}{2}} + 0.007\ \S$$

in which

Q = discharge, in cubic feet per second per foot of length of weir;

* "Lowell Hydraulic Experiments," by J. B. Francis, pp. 131 and 133.

† *Loc. cit.*, p. 117.

‡ *Loc. cit.*, p. 135.

§ *Transactions*, Am. Soc. C. E., Vol. XII, pp. 11 and 82.

h = measured head, or the vertical distance, in feet, between the horizontal plane containing the crest of the weir and the plane surface of the water in the channel of approach;

and $h' = \frac{V^2}{2\,g}$, V being the mean velocity of the water in the channel of approach, and g the acceleration of gravity.

(3).—The Bazin Formula.

Bazin's is the only weir formula that has been proposed, up to this time, which, for accurate results, does not necessitate taking into account the velocity of the water in the channel of approach. His formula, in English units, is as follows:

$$Q = \frac{2}{3}\left(0.6075 + \frac{0.0148}{h}\right)\left[1 + 0.55\left(\frac{h}{p+h}\right)^2\right] h \sqrt{2\,gh}$$

in which

Q = discharge, in cubic feet per second per foot of length of weir;

h = the measured head, or the vertical distance, in feet, between the horizontal plane containing the crest of the weir and the plane surface of the water in the channel of approach;

p = the vertical distance between the bottom of the channel of approach and the horizontal plane containing the weir's crest;

g = the acceleration of gravity, in feet per second per second.

(4).—Formulas Proposed by the Writer.

Equations of the form, $Q = m\,h^n$, are derived in this paper for all the weirs of all the forms herein considered. The great variation in the values of m and n shown on Plates LXXXVI, LXXXIX, and XCI, and in Tables C, D, E, and F, are strong arguments against the use of only one formula for computing the discharge over weirs of various sizes, especially when the quantity of water to be measured varies through wide limits.

Again, by the methods explained in this paper, diagrams can be prepared that give the same results as the formulas of the form, $Q = m\,h^n$. By the diagrams herein presented, the discharges over nearly all well-known experimental weirs can be found. Based on the results given by these experiments, other diagrams are presented which indicate with accuracy the discharge over weirs of almost all forms and sizes.

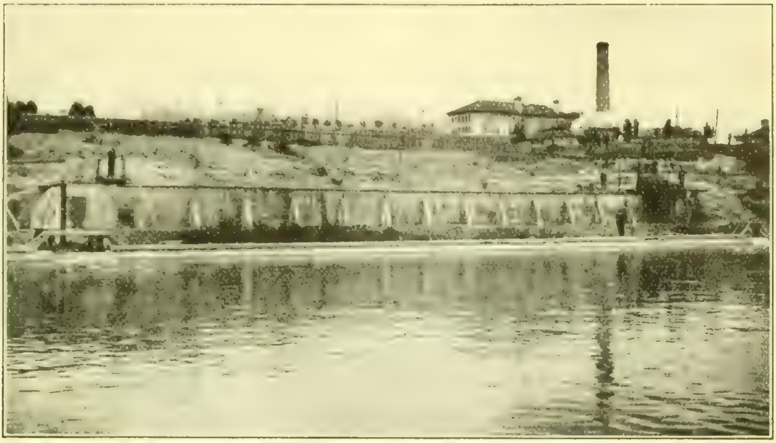


FIG. 7.—GENERAL VIEW OF HYDRAULIC LABORATORY OF UNIVERSITY OF UTAH AND THIRTEENTH EAST STREET RESERVOIR.

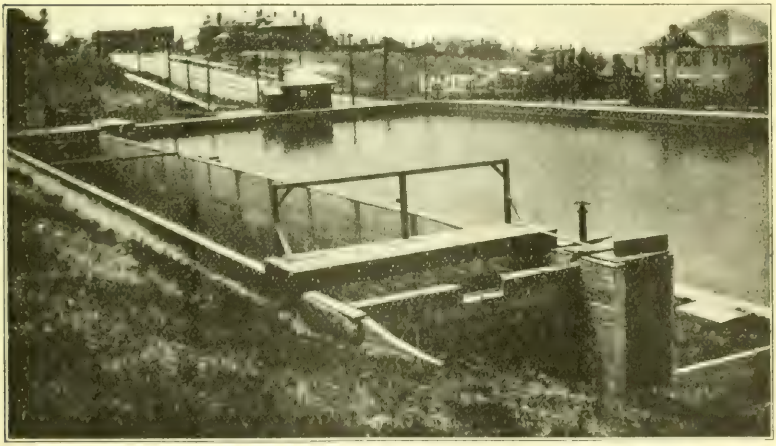
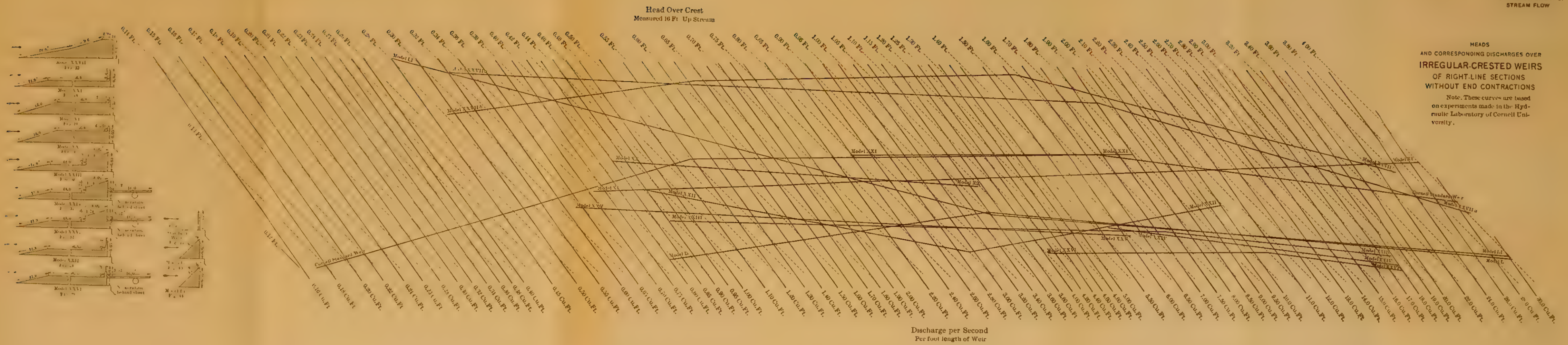


FIG. 8.—MEASURING BASIN, HYDRAULIC LABORATORY OF UNIVERSITY OF UTAH, AND THIRTEENTH EAST STREET RESERVOIR.

HEADS
AND CORRESPONDING DISCHARGES OVER
IRREGULAR-CRESTED WEIRS
OF RIGHT-LINE SECTIONS
WITHOUT END CONTRACTIONS

Note. These curves are based on experiments made in the Hydraulic Laboratory of Cornell University.



This formula, $Q = m\ h^n$, may be written

$$\log.\ Q = n \log.\ h + \log.\ m.$$

If the logarithms of heads of less than 1 ft. be expressed as negative quantities, the Thacher rule may be used for computing the values of $n \log.\ h$. If, to the results thus obtained, the constant quantity, $\log.\ m$, be added, the quantities obtained are the logarithms of the discharges desired.

By this method, computations of quantities of discharge by any formula of the form, $Q = m\ h^n$, are made as easily and quickly as by the Francis formula, $Q = 3.33\ H^{\frac{3}{2}}$.

For finding the discharge over a weir, the diagram has two advantages over the formula: First, it gives results without computation; secondly, results obtained by the diagram do not appear to contain an accuracy which is not warranted.

D.—Comparative Accuracy of the Formulas.

The Francis formula has been used more than any other, for the reason, perhaps, that engineers, generally, have constructed weirs so as to feel satisfied, justly or otherwise, with this formula, without making a correction for the velocity of approach. By doing so they have avoided what Francis himself has very properly called "the troublesome calculation for correcting the depth on the weir."*

In the right-hand portion of Fig. 8, Plate LXXXVI*a*, the points located symmetrically with respect to the line having the equation, $Q = m\ h^{1.5032}$ (in which $\log.\ m = 0.5257$, or $m = 3.355$), show how accurately this equation fits the Francis experiments when they have not been corrected for velocity of approach. Two broken lines are shown passing through the points in the left-hand portion of this drawing. That marked "Francis Formula" shows where these points should be if the equation fitted them perfectly. Those points to which the velocity of approach has not been applied are to the right of this line at a distance which indicates that, for a head of 1.0 ft., the formula gives a computed discharge 0.9% too small (see scale on Plate LXXXVI*a*). The error is slightly less for lower heads. When to these experiments "the troublesome calculation for velocity of approach" has been applied, the Francis formula, for a head of 1.0 ft., still gives a result in error 0.2%, as the diagram shows, and the equa-

* "Lowell Hydraulic Experiments," p. 135.

tion, $Q = m\ h^{1.4964}$ (in which log. $m = 0.5214$, or $m = 3.322$), fits these experiments almost perfectly.

A comparison of the values given in Table 8A, and in Table XIII of the "Lowell Hydraulic Experiments," shows that the computed or corrected heads in these Francis experiments do not agree. This lack of agreement is due to the fact that Francis based his corrections on the velocity of approach 6 ft. up stream from the crest, and the writer's are based on a velocity of approach computed from the cross-section of the channel just up stream from the crest of the weir. These results would agree if the bottom of the channel of approach were level, or, in other words, if the cross-section of the channel of approach were constant.

Note what effect this small difference in cross-section makes, and then imagine the uncertainty that necessarily comes into the results by measuring water with a weir above which sediment and gravel accumulate until at times the depth of the channel of approach decreases to zero. In practice, such a condition often prevails.

It may be well to draw attention at this point to the accuracy with which equations of the form, $Q = m\ h^n$, can be made to fit experiments by the methods herein presented, and also to the clearness with which the degree of accuracy attained can be seen.

It will be noted that, of these two broken lines, that on the left fits the results better than that on the right. The latter represents the Francis formula, and the former is the line that best fits the Francis experiments. For a head of 1 ft. there is a difference in quantity of only 0.17% (by the scale on Plate LXXXVI*a*) between the results of the Francis formula and those of the "best fitting line", yet this small difference is shown clearly and accurately on the diagram. The broken line in the extreme right-hand side of the figure shows the results obtained by using the final diagram for a weir of this height. For a head of 1 ft. it gives quantities about 0.7% less than the Francis results not corrected for velocity of approach, and quantities about 1.8% less than the Francis results when these are thus corrected. It is the influence of other experiments that draws this line so far to the right.

E.—Method of Determining the Proposed Formulas.

No exhaustive study of the quantities discharged over a weir for known heads is required to discover that one equation of the form,

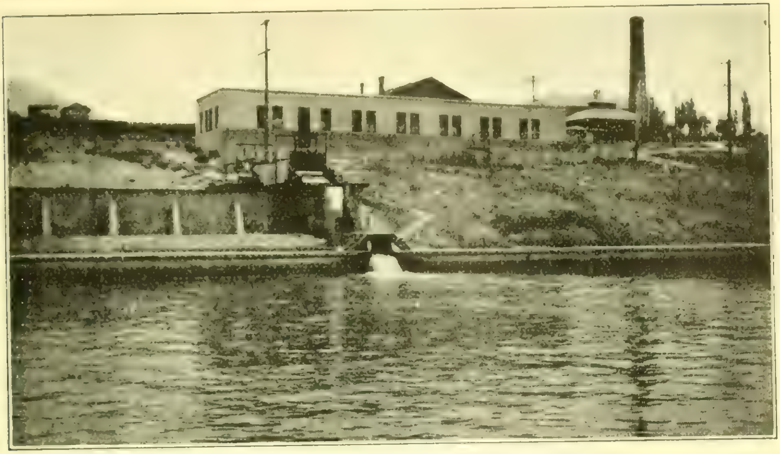


FIG. 9.—LABORATORY BUILDINGS, CANALS, DIVERTING DEVICE, AND WASTE-WAY OF HYDRAULIC LABORATORY OF UNIVERSITY OF UTAH.

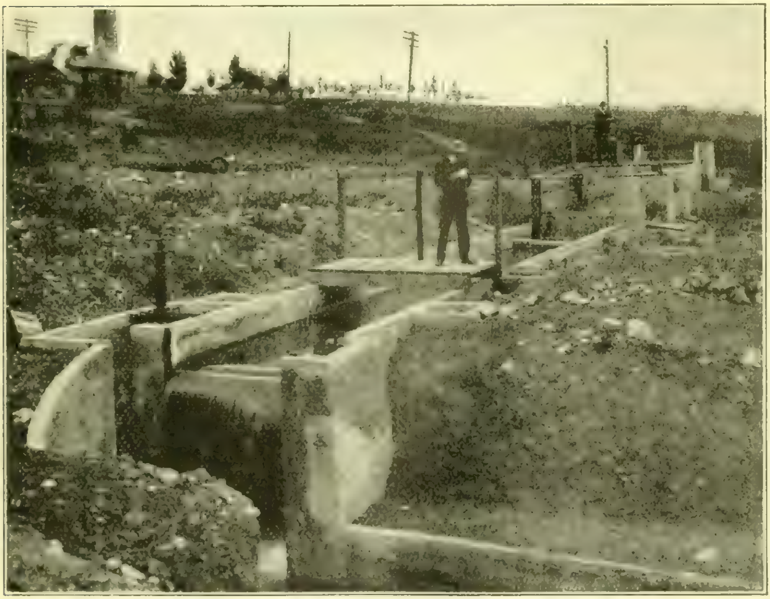
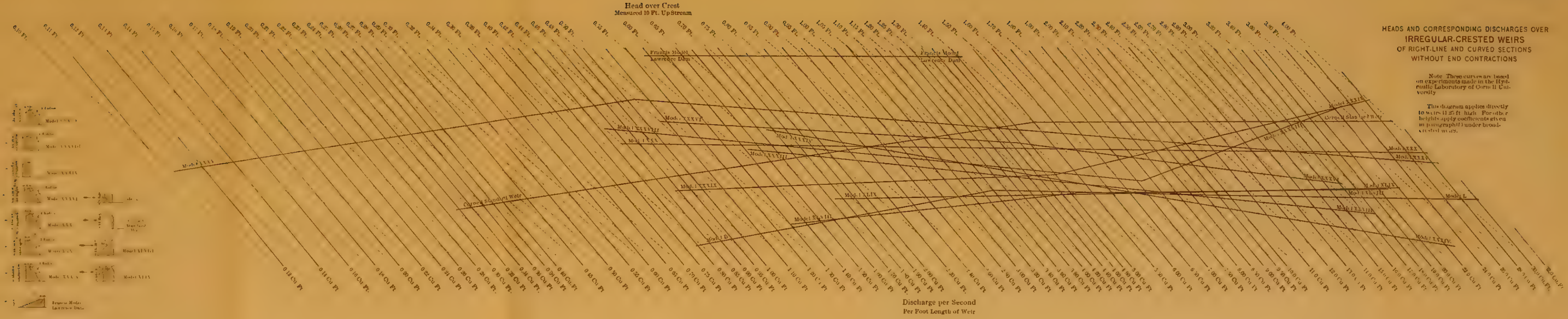


FIG. 10.—RECEIVING BASIN, CANAL NO. 1, WEIR NO. 1, CANAL NO. 2, AND WEIR NO. 2 OF HYDRAULIC LABORATORY OF UNIVERSITY OF UTAH.



HEADS AND CORRESPONDING DISCHARGES OVER IRREGULAR-CRESTED WEIRS OF RIGHT-LINE AND CURVED SECTIONS WITHOUT END CONTRACTIONS

Note. These curves are based on experiments made in the Hydraulic Laboratory of Cornell University.

This diagram applies directly to weirs 11.25 ft. high. For other heights apply coefficients given in paragraph [illegible] under broad-crested weirs.

$Q = m\,h^n$, with constant values for m and n will not give the discharge with a high degree of accuracy if the values of h cover a wide range. Nevertheless, when the values of h cover but a limited range, the highest degree of accuracy that the experimental data warrant can be obtained with an equation of this form.

Here, as elsewhere in this paper, wherever Q is used, it designates the quantity of water discharged over a weir, in cubic feet per second per foot of length of weir; h is used to designate the observed head of water on a weir, in feet, unless otherwise plainly stated. (This h is not measured in still water.)

With given values of h and the corresponding values of Q, efforts have been made to determine equations of the form named that satisfy these values.

First, plotting on logarithmic paper was tried, but even when using paper with a 20-in. base, the curvature of the lines determined by the plotted points was so slight that the best fitting lines that could be obtained were more likely, when their equations were applied to the given data, to be ill- than to be well-fitting.

Secondly, the logarithms of the Q's and the h's, on a scale as large as could be used with any degree of convenience, were plotted; but the results were little if any more satisfactory than those obtained from the plotting on logarithmic paper.

Thirdly, the method of finding the centers of gravity of the upper and lower halves of the curves that result from plotting the logarithms and passing a line analytically through the points thus found, was used. This method gives results somewhat more satisfactory than the others, when applied to the determination of a single line or equation for the whole set of experiments; but if one equation does not give satisfactory results, this method gives little or no indication of the number of equations necessary, or the point at which divisions should be made, before attempting to find the two or more equations required. This method of investigation had been applied faithfully to nearly all the experiments herein presented, and gave results which were considered very satisfactory, before the final method was discovered.

Fourthly, by the final method of treating these experiments, lines having equations which give results with a degree of accuracy as high as the experiments warrant can be passed through the points plotted.

By this method the trial equation, $Q = m\ h^{1.5000}$ (log. $m = 0.5000$), is first applied. The differences between the logarithms of the quantities measured and the logarithms of the quantities computed by this trial formula, are plotted; the logarithms of the heads are used as ordinates, and the differences just mentioned as abscissas. The scale on which the differences are plotted is ten times that on which the heads are plotted, so that the angles and curves of the various lines are greatly exaggerated; with little difficulty, therefore, the number of equations needed to fit the experiments is selected, and the lines representing these equations are easily and readily drawn.

Taking the logarithms of both sides of the general equation,

$$Q = m\ h^n,$$

gives log. $Q = n$ log. $h +$ log. m.

This is the equation of a straight line the intercept of which on the Y or log. Q axis (the line having the equation, log. $h = 0$) is log. m; n is the slope of the line, or the tangent of the angle the line makes with the X or log. h axis (the line having the equation, log. $Q = 0$).

Let YY be the log. Q axis, and let XX be the log. h axis (as shown by Fig. A, at the right of Plate LXXXVI*b*). The log. h axis is put in the vertical position because it is usual to measure and represent heads in that direction.

The locus of the trial formula, or equation, log. $Q = 1.5000$ log. h $+ 0.5000$, is the line, ab. The point, a, on the log. Q axis is found by substituting in the foregoing equation log. $h = 0$, and the point, b, on the line, log. $h = -1$, is found by substituting in that equation log. $h = -1$. The distance, Oa, or the "intercept on the Y axis", is 0.5000 in this particular equation, or it is log m in the general equation. The value of n is (from the equation of a straight line) the tangent of the angle the line makes with the log. h axis, that is, the tangent of the angle, Oca. In this case it is

$$\frac{Oa}{Oc} = \frac{ad}{db} = \frac{1.5}{1.0} = 1.5.$$

Lines actually representing the equations which fit the data considered vary but slightly from the line, ab. Hence, the differences in the values of log. Q cannot be shown with sufficient accuracy on a drawing of reasonable size when rectangular axes are used. The line, ab, therefore, is made vertical on the same horizontal lines, and from

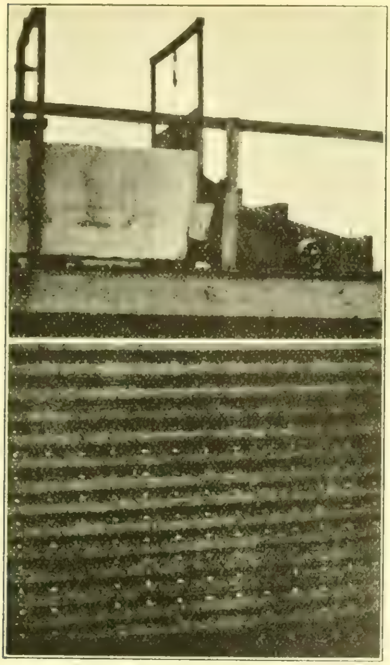


FIG. 11.—DIVERTING DEVICE AND BAFFLES IN SOUTH END OF MEASURING BASIN, HYDRAULIC LABORATORY OF UNIVERSITY OF UTAH.

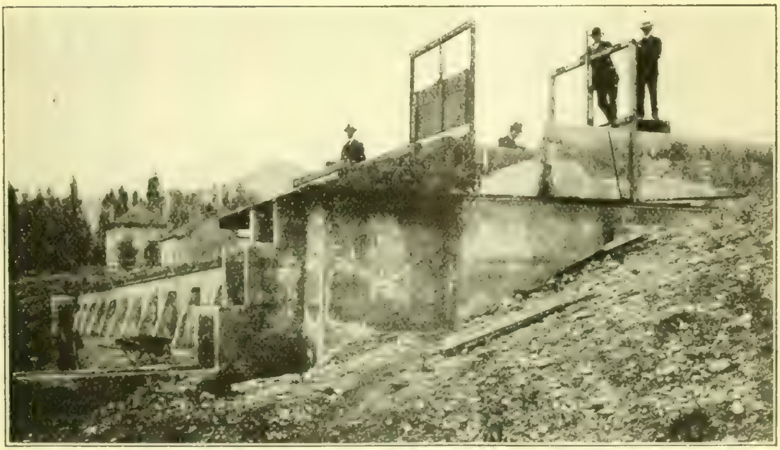


FIG. 12.—WEIR NO. 3, DIVERTING DEVICE, AND WASTE-WAY OF HYDRAULIC LABORATORY OF UNIVERSITY OF UTAH.

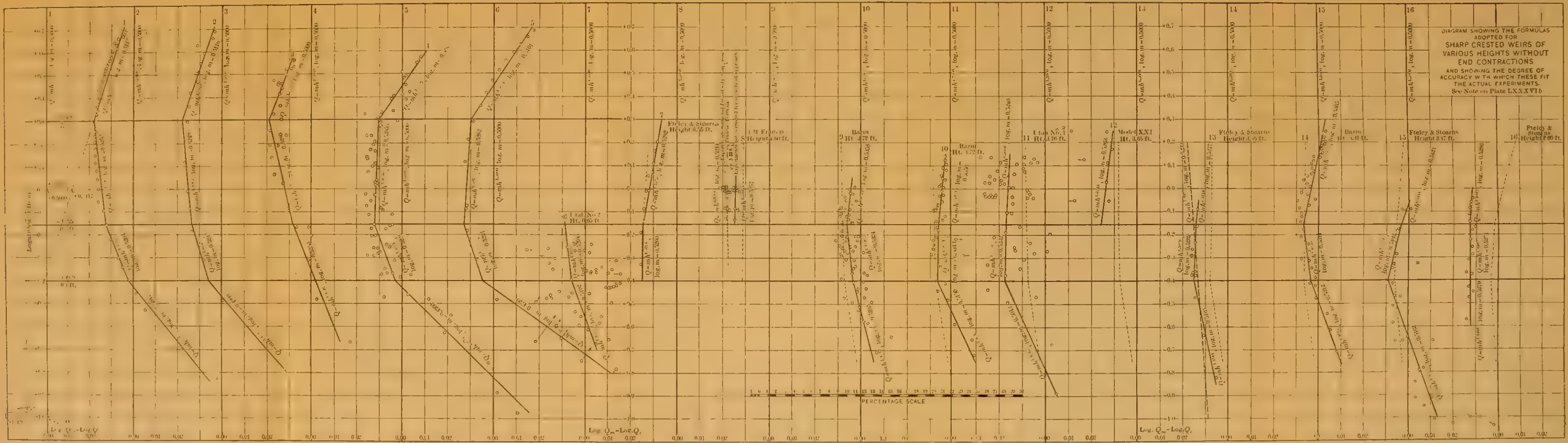


DIAGRAM SHOWING THE FORMULAS
ADOPTED FOR
SHARP CRESTED WEIRS OF
VARIOUS HEIGHTS WITHOUT
END CONTRACTIONS
AND SHOWING THE DEGREE OF
ACCURACY WITH WHICH THESE FIT
THE ACTUAL EXPERIMENTS.
See Note on Plate LXXXVIb
PERCENTAGE SCALE
Fteley & Stearns Height 6.55 ft.
Bazin Ht. 3.72 ft.
Model XXI Ht. 3.65 ft.
Fteley & Stearns Height 3.17 ft.
Log. Q_m - Log. Q_c

it, to right and to left, the computed differences of the logarithms of the quantities are plotted.

Example.—On Plate LXXXVI*a*, Fig. 1, the vertical line having the equation, log. Q = 1.5000 log. h + 0.5000, or $Q = m\, h^{1.5000}$ (log. m = 0.5000), is marked 1. The points plotted with reference to this line are shown in the curve marked 1. The quantities plotted are those in Column 6 of Table 1, and the logarithms of the heads as in Column 3. The quantities in Column 6 are the differences of the logarithms of Q_m (measured) and Q_c (computed by the trial formula).

The horizontal scale of this drawing (as originally plotted) is 0.01 (logarithm) to the inch; these differences, therefore, can be and are plotted to the fourth decimal place. If a drawing similar to that shown by Fig. A, Plate LXXXVI *b*, were made to this same scale, the line, *ab*, between the lines, log. $h = -1.0$ and log. $h = 0.71$, that is, between the lines representing heads of 0.1 ft. and 5.1 ft. (values well within the limits of Plates LXXXVI*a* and LXXXVI*b*), would be 22 ft. long. To show, on such a scale, all the matter on Plates LXXXVI*a* and LXXXVI*b* would require a drawing 33 ft. long if the curves were placed at the same horizontal distance from each other, though the length of Plate LXXXVI*, as originally drawn, is only 11 ft. On the two parts of this plate the lines and curves are located so that they may be used and studied conveniently; but, if one curve occupied a horizontal distance of 22 ft., it would be impossible to get results of value from its points, as, in most cases, they would be many feet apart. Such lines, being practically horizontal, would give very poor points of intersection with the horizontal lines which represent the heads; whereas those used on Plate LXXXVI*a* and LXXXVI*b* give good points of intersection.

After plotting these points, right lines were drawn to fit them, and the equations of the lines thus drawn have been determined from their points of intersection with the lines, log. $h = 0$ and log. $h = -1$. As explained previously, the reference line intersects the line, log. $h = -1.0$, at the point, -1.0000, and the line, log. $h = 0.0$, at the point, $+ 0.5000$.

In Fig. 1, Plate LXXXVI*a*, it will be observed that the portion of the curve above log. h = 0.3010, when produced downward, as shown by the dotted line, intersects the line, log. $h = 0.0000$, at the

* For convenience, Plate LXXXVI has been divided into two parts, *a* and *b*.

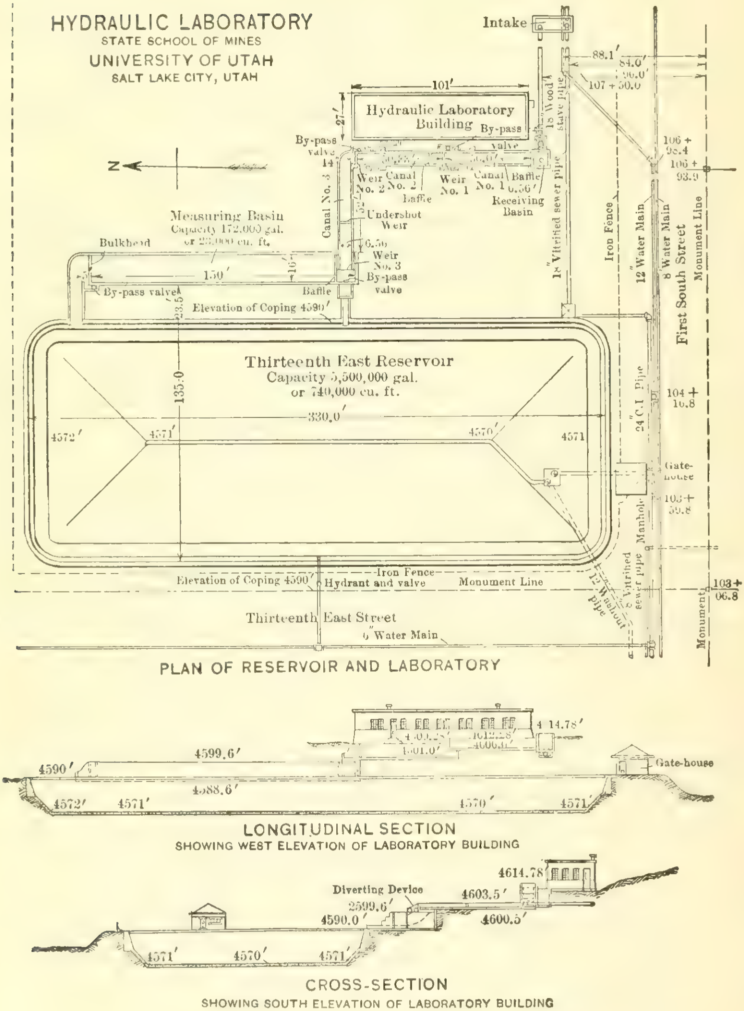

HYDRAULIC LABORATORY
STATE SCHOOL OF MINES
UNIVERSITY OF UTAH
SALT LAKE CITY, UTAH
Intake
Hydraulic Laboratory Building
Measuring Basin
Thirteenth East Reservoir
Capacity 5,500,000 gal.
or 740,000 cu. ft.
First South Street
Thirteenth East Street
PLAN OF RESERVOIR AND LABORATORY
LONGITUDINAL SECTION
SHOWING WEST ELEVATION OF LABORATORY BUILDING
CROSS-SECTION
SHOWING SOUTH ELEVATION OF LABORATORY BUILDING

FIG. 13.

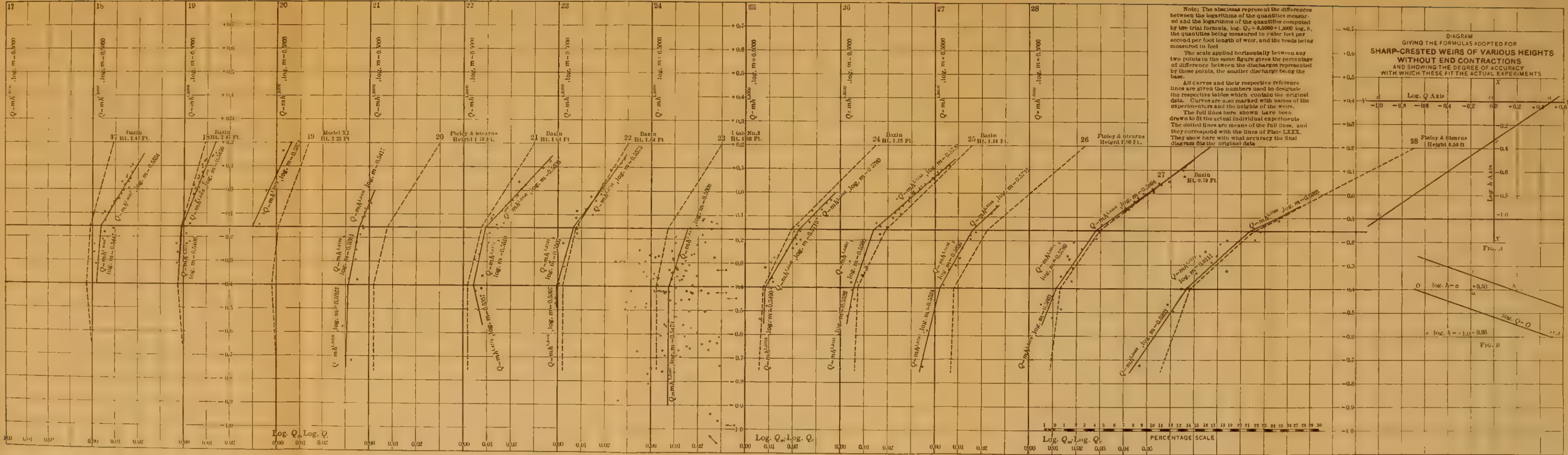


DIAGRAM
GIVING THE FORMULAS ADOPTED FOR
SHARP-CRESTED WEIRS OF VARIOUS HEIGHTS
WITHOUT END CONTRACTIONS
AND SHOWING THE DEGREE OF ACCURACY
WITH WHICH THESE FIT THE ACTUAL EXPERIMENTS
Note; The abscissas represent the differences between the logarithms of the quantities measured and the logarithms of the quantities computed by the trial formula, log. Q_c = 0.5000 + 1.5000 log. h, the quantities being measured in cubic feet per second per foot length of weir, and the heads being measured in feet
The scale applied horizontally between any two points in the same figure gives the percentage of difference between the discharges represented by these points, the smaller discharge being the base.
All curves and their respective reference lines are given the numbers used to designate the respective tables which contain the original data. Curves are also marked with names of the experimenters and the heights of the weirs.
The full lines here shown have been drawn to fit the actual individual experiments The dotted lines are means of the full lines, and they correspond with the lines of Plate LXXX. They show here with what accuracy the final diagram fits the original data
17 Bazin Ht. 2.47 Ft.
18 Bazin Ht. 2.46 Ft.
19 Model XI Ht. 2.23 Ft.
20 Fteley & Stearns Height 1.70 Ft.
21 Bazin Ht. 1.64 Ft.
22 Bazin Ht. 1.64 Ft.
23 Utah No.3 Ht. 1.55 Ft.
24 Bazin Ht. 1.15 Ft.
25 Bazin Ht. 1.14 Ft.
26 Fteley & Stearns Height 1.00 Ft.
27 Bazin Ht. 0.79 Ft.
28 Fteley & Stearns Height 0.50 ft
Log. Q_m-Log. Q_c
PERCENTAGE SCALE
Log. Q Axis
Log. h Axis
FIG. A
log. h = 0
log. Q = O
FIG. B

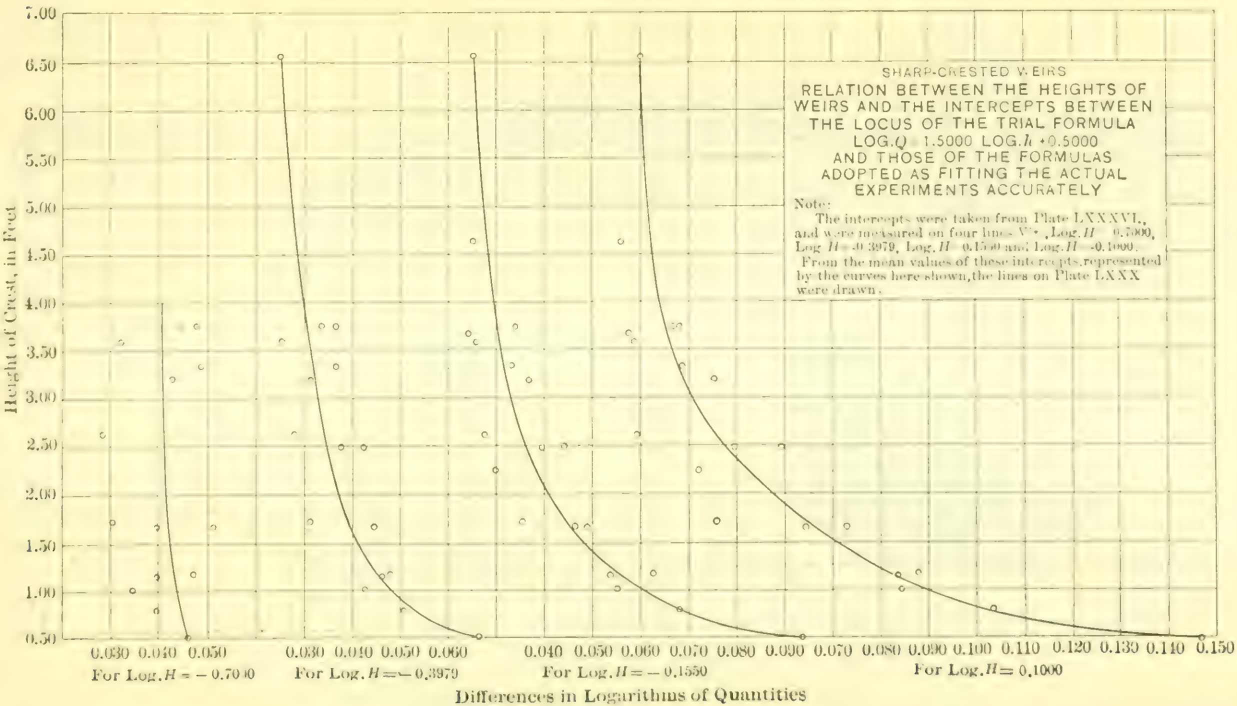

SHARP-CRESTED WEIRS
RELATION BETWEEN THE HEIGHTS OF WEIRS AND THE INTERCEPTS BETWEEN THE LOCUS OF THE TRIAL FORMULA
LOG. Q = 1.5000 LOG. h + 0.5000
AND THOSE OF THE FORMULAS ADOPTED AS FITTING THE ACTUAL EXPERIMENTS ACCURATELY
Note:
The intercepts were taken from Plate LXXXVI., and were measured on four lines, Viz., Log. H = -0.7000, Log. H = -0.3979, Log. H = -0.1550 and Log. H = 0.1000.
From the mean values of these intercepts, represented by the curves here shown, the lines on Plate LXXX were drawn.
Height of Crest, in Feet
7.00
6.50
6.00
5.50
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.030 0.040 0.050
For Log. H = -0.7000
0.030 0.040 0.050 0.060
For Log. H = -0.3979
0.040 0.050 0.060 0.070 0.080 0.090
For Log. H = -0.1550
0.070 0.080 0.090 0.100 0.110 0.120 0.130 0.140 0.150
For Log. H = 0.1000
Differences in Logarithms of Quantities

Fig. 14.

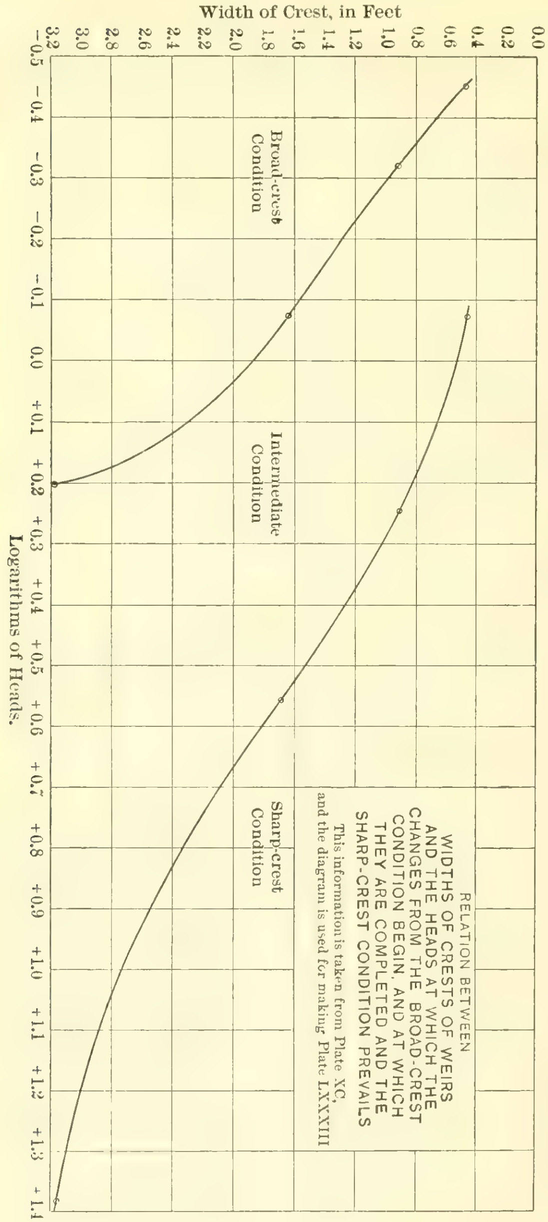
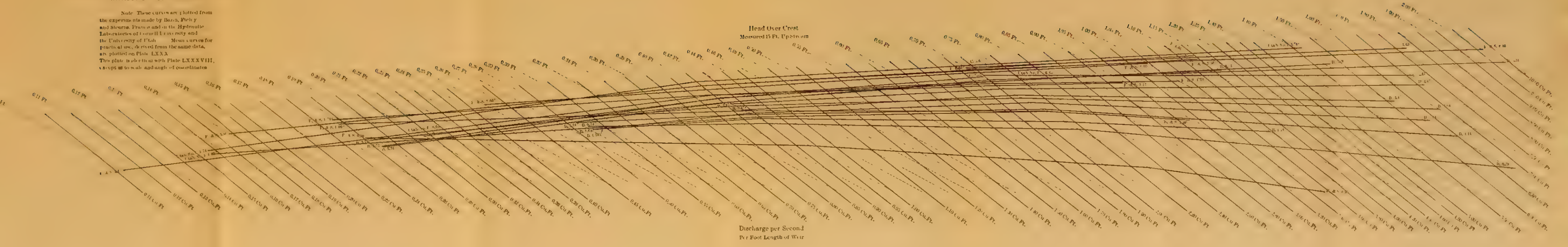

Width of Crest, in Feet
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
−0.5
−0.4
−0.3
−0.2
−0.1
0.0
+0.1
+0.2
+0.3
+0.4
+0.5
+0.6
+0.7
+0.8
+0.9
+1.0
+1.1
+1.2
+1.3
+1.4
Logarithms of Heads.
Broad-crest Condition
Intermediate Condition
Sharp-crest Condition
RELATION BETWEEN
WIDTHS OF CRESTS OF WEIRS AND THE HEADS AT WHICH THE CHANGES FROM THE BROAD-CREST CONDITION BEGIN, AND AT WHICH THEY ARE COMPLETED AND THE SHARP-CREST CONDITION PREVAILS
This information is taken from Plate XC, and the diagram is used for making Plate LXXXIII

FIG. 15.

HEADS AND CORRESPONDING DISCHARGES OVER
SPECIFIC SHARP CRESTED WEIRS OF VARIOUS HEIGHTS
WITHOUT END CONTRACTIONS

Note. These curves are plotted from the experiments made by Bazin, Fteley and Stearns, Francis and in the Hydraulic Laboratories of Cornell University and the University of Utah. Mean curves for practical use, derived from the same data, are plotted on Plate LXXX.
This plate is identical with Plate LXXXVIII, except as to scale and angle of coordinates.



point, log. $Q = 0.5000 + 0.0117 = 0.5117$. The figures marked on the plate will make this point clear.

This same line (on the original drawing) intersects the line, log. $h = -1.0000$, 2.12 in. to the left of the point at which the reference line intersects it, giving, therefore, for the point of intersection, the value, $-1.0000 - 0.0212 = -1.0212$ for log. Q.

Next find the value of n in the equation, log. $Q = n$ log. $h +$ log. m. Referring to Fig. 2, Plate LXXXVI*a* (right hand end), the value of n is $\frac{ad}{db}$. In general, ad is the sum of aO and Od. In this particular case, as just shown, aO is 0.5117 and Od is 1.0212; therefore, ad, being the sum of these two values, is 1.5329. In this case $db = 1$, therefore $n = \frac{ad}{db} = \frac{1.5329}{1.0000} = 1.5329$, and the equation sought is $Q = m\, h^{1.5329}$, in which log. $m = 0.5117$.

In a similar manner, equations have been found for all the curves on Plates LXXXVI*a*, LXXXVI*b*, LXXXIX, XCI*a*, XCI*b*, and on Fig. 14, and the resulting values of n, m, and log. m, together with the limiting values of h between which these values apply, are given in Tables C, D, E, and F, as well as on the curves on the plates.

List of Tables.

The following is a list of all the Tables accompanying this paper. Some of these tables are reproduced, but, as the others are too voluminous to be published here, they have been filed in the Library of the Society, where they may be examined by those specially interested. Table 0 is printed on page 1525; Table 1 (as a sample of Tables 1 to 67) is printed on page 1549; and Tables C, D, E, and F are printed on pages 1550 to 1554.

* This Table is printed with the paper as a sample of Tables 1 to 67, inclusive.

Broad-Crested Weirs Without End Contractions.

(Experiments in the Hydraulic Laboratory of Cornell University. Models Built Over the Upper Standard Weir, Height 11.25 Feet, Length 16.00 Feet.)

F.—Actual Determination of the Formulas.

Formulas of the proposed form, namely, $Q = m\ h^n$, have been prepared for four different classes of weirs without end contractions:

(1) Sharp-crested weirs;

(2) Broad-crested weirs;

(3) Irregular weirs with cross-sections of right lines;

(4) Irregular weirs with cross-sections of right lines and curves.

The values of the constants for the formulas derived are given in Tables C, D, E, and F.

As measuring the head on the crest of a weir with a "tape" is perhaps the simplest and best method in actual field practice, all heads

measured otherwise than with a tape, except where specifically noted, have been reduced to equivalent tape readings by using the curves on Plates XCII and XCIII. The distances up stream from the crest at which these tape readings have been taken are given, with the tabulation of the data, in Tables 1 to 28 and 38 to 67, inclusive, and also on the discharge diagrams, Plates LXXX, LXXXIII, LXXXIV, and LXXXV.

(1).—For Sharp-Crested Weirs.

(*a*).—*General Statement.*—Equations are herein derived and diagrams devised for determining the discharge over all the weirs of this class on which accurate experiments, on a large scale, have been made. The adopted equations for these weirs, and the limits of the heads between which each may be applied, are given in Table C.

The experiments in which the water was measured volumetrically, or with weirs rated by volumetric measurement, include those of Francis, Fteley and Stearns, Bazin, and those made in the hydraulic laboratory of the University of Utah. These experiments have been made with weirs having heights ranging from the Fteley and Stearns weir, 0.50 ft. high (5 ft. long), to the Utah weir No. 2, 6.65 ft. high (6.55 ft. long). The experiments of Francis were made on only one weir of this class, and it was 4.60 ft. high and 9.992 ft. long.*

The Cornell 6-ft. Francis piezometer was constructed for the purpose of duplicating the apparatus used by Francis for measuring heads. Observe that the curve on Plate XCIII, as determined by the readings of this piezometer, runs across nearly all the other curves for heads of less than 1 ft. It seems hardly reasonable that the readings for these small heads should increase so much more rapidly, as the zero point is approached, than do those of the other devices; and as the pressure orifice for this piezometer was between the two gates in the lower end of the canal, it is probable that a small leak induced a slight velocity toward the opening. The impact due to this velocity would account for the small increase in the reading. It is for this reason that the heads measured by Mr. Francis and those measured by Messrs. Fteley and Stearns, using this same method, have not been reduced to equivalent tape readings.

(*b*).—*Francis Experiments.*—The Francis experiments (Table 8) are plotted in Fig. 8, Plate LXXXVI*a*. The height of this weir was

* "Lowell Hydraulic Experiments," pp. 124, 125.

PLATE LXXXVIII.
PAPERS, AM. SOC. C. E
SEPTEMBER, 1913.
LYMAN ON
WEIR MEASUREMENT OF
STREAM FLOW.

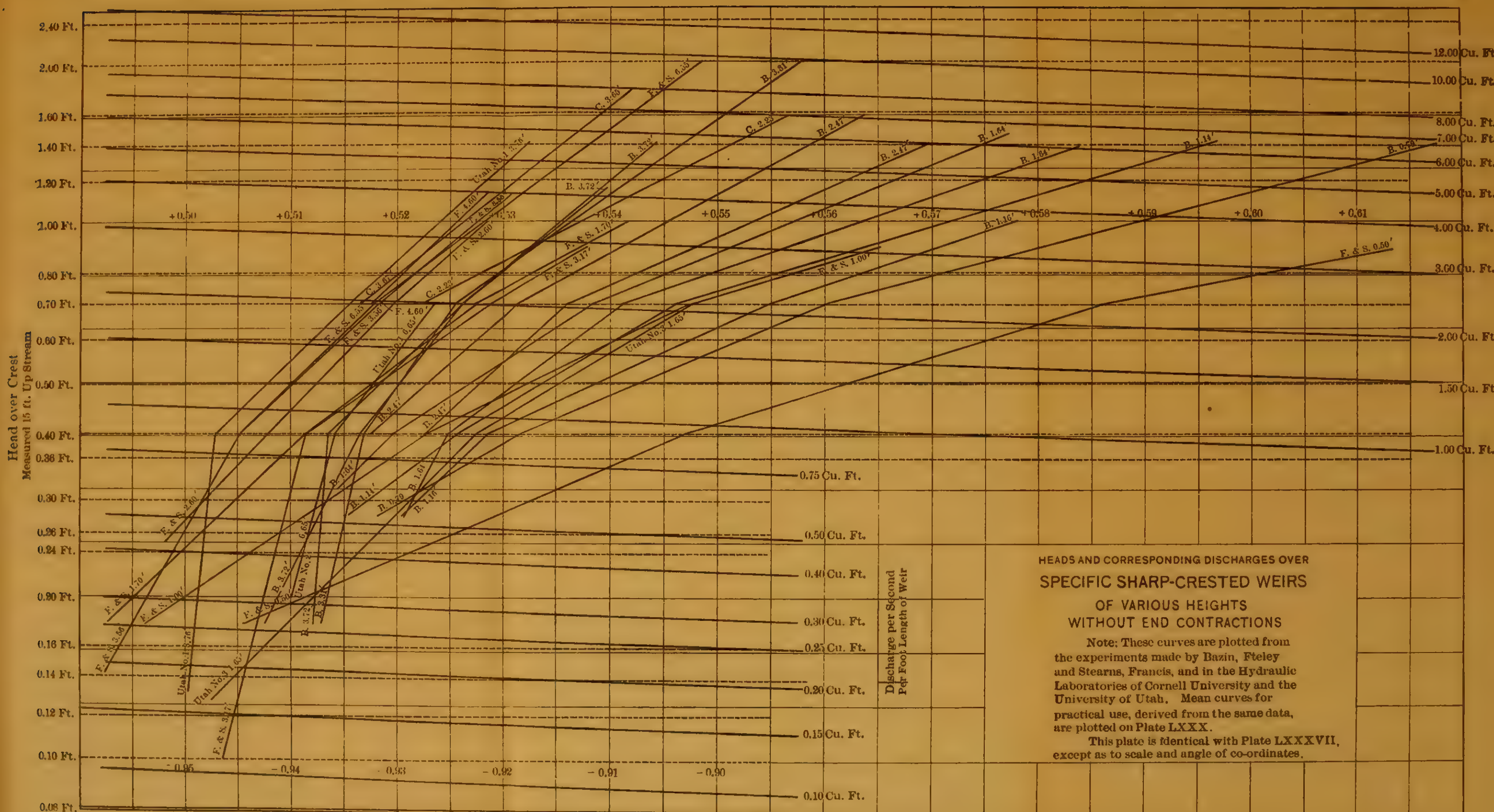


TABLE 1.*—SHARP-CRESTED WEIRS.

Computations by Dr. Schoder, Based on the Bazin Formula, for a Weir of Height 11.25 ft.

(1) No. of exp.	(2) Assumed head.	(3) 15-ft. tape head.	(4) Log. Q_c	(5) Log. Q_B	(6) Log. Q_B — Log. Q_c	(7) Q_c	(8) Q_B
	5.00		1.5485	1.5846	0.0361	35.361	38.421
	4.90		1.5353	1.5709	0.0356	34.300	37.234
	4.80		1.5217	1.5569	0.0352	33.243	36.049
	4.70		1.5080	1.5426	0.0346	32.111	34.881
	4.60		1.4940	1.5282	0.0342	31.189	33.742
	4.50		1.4798	1.5132	0.0334	30.186	32.600
	4.40		1.4651	1.4980	0.0329	29.181	31.479
	4.30		1.4501	1.4825	0.0324	28.190	30.377
	4.20		1.4348	1.4667	0.0321	27.215	29.286
	4.10		1.4191	1.4504	0.0313	26.248	28.213
	4.00		1.4030	1.4338	0.0308	25.293	27.155
	3.90		1.3865	1.4168	0.0303	24.350	26.111
	3.80		1.3696	1.3994	0.0298	23.421	25.085
	3.70		1.3523	1.3815	0.0292	22.506	24.072
	3.60		1.3344	1.3631	0.0287	21.597	23.074
	3.50		1.3160	1.3443	0.0283	20.701	22.097
	3.40		1.2972	1.3250	0.0278	19.824	21.135
	3.30		1.2778	1.3051	0.0273	18.958	20.187
	3.20		1.2577	1.2845	0.0268	18.101	19.253
	3.10		1.2370	1.2634	0.0264	17.258	18.339
	3.00		1.2157	1.2416	0.0259	16.432	17.441
	2.90		1.1935	1.2191	0.0256	15.613	16.561
	2.80		1.1707	1.1958	0.0251	14.815	15.697
	2.70		1.1471	1.1718	0.0247	14.031	14.815
	2.60		1.1224	1.1468	0.0244	13.256	14.021
	2.50		1.0969	1.1209	0.0240	12.250	13.209
	2.40		1.0703	1.0940	0.0237	11.760	12.417
	2.30		1.0426	1.0659	0.0233	11.031	11.638
	2.20		1.0136	1.0367	0.0231	10.328	10.882
	2.10		0.9833	1.0061	0.0228	9.623	10.142
	2.00		0.9515	0.9741	0.0226	8.943	9.422
	1.90		0.9181	0.9406	0.0225	8.281	8.722
	1.80		0.8828	0.9052	0.0224	7.635	8.039
	1.70		0.8456	0.8678	0.0222	7.008	7.376
	1.60		0.8062	0.8284	0.0222	6.400	6.736
	1.50		0.7640	0.7864	0.0224	5.808	6.115
	1.40		0.7192	0.7415	0.0223	5.238	5.515
	1.30		0.6709	0.6935	0.0224	4.687	4.937
	1.20		0.6186	0.6416	0.0230	4.155	4.381
	1.10		0.5619	0.5854	0.0235	3.646	3.849
	1.00		0.5000	0.5239	0.0239	3.162	3.342
	0.90		0.4313	0.4551	0.0238	2.700	2.852
	0.80		0.3545	0.3806	0.0261	2.262	2.402
	0.70		0.2675	0.2951	0.0276	1.851	1.973
	0.60		0.1671	0.1970	0.0299	1.469	1.574
	0.50		0.0483	0.0814	0.0331	1.118	1.206
	0.45		—0.0202	0.0150	0.0352	0.955	1.035
	0.40		—0.0970	—0.0590	0.0380	0.800	0.873
	0.35		—0.1840	—0.1425	0.0415	0.655	0.720
	0.30		—0.2844	—0.2385	0.0459	0.519	0.577
	0.25		—0.4301	—0.3508	0.0523	0.395	0.446
	0.20		—0.5485	—0.4865	0.0620	0.283	0.326
	0.15		—0.7360	—0.6588	0.0772	0.188	0.219
	0.10		—1.0000	—0.8935	0.1065	0.100	0.128

* Table 1 is here reproduced as a sample of the tables numbered 1 to 8, 8A, and 9 to 67. All these tables, together with Tables A, B, C, D, E, and F, are filed in the Library of the Society, where they may be examined by those specially interested.

4.60 ft. The results, obtained by applying the trial formula to the Francis experiments without correcting for velocity of approach, are shown by the points, at the right of the figure, through which a full

TABLE C.—SHARP-CRESTED WEIRS.

Values of m and n to be used in the equation, $Q = m\,h^n$, for computing the discharge, in cubic feet per second per foot of length of weir, and the limiting value of the heads to be used in the corresponding equation.

(1) No. of table.	(2) Height of weir.	(3) n.	(4) Log. m.	(5) m.	(6) Limits of Head, in Feet. Upper.	(7) Limits of Head, in Feet. Lower.	(8) Name of experimenter.
1	11.25	1.5329	0.5117	3.249	5.00	2.00	Application of Bazin's Formula by Dr. Schoder.
		1.4879	0.5252	3.351	2.00	0.70	
		1.4567	0.5204	3.314	0.70	0.40	
		1.4161	0.5041	3.192	0.40	0.10	
2	11.25	1.5346	0.5116	3.248	4.90	2.00	Application of Bazin's Formula by Professor Williams.
		1.4902	0.5249	3.349	2.00	0.70	
		1.4695	0.5217	3.324	0.70	0.40	
		1.4130	0.4990	3.155	0.40	0.16	
3	11.25	1.5373	0.5099	3.235	3.70	2.00	Cornell Hydraulic Laboratory.
		1.4767	0.5280	3.373	2.00	0.70	
		1.4592	0.5253	3.352	0.70	0.20	
4	6.65	1.5702	0.5087	3.226	4.00	2.00	Cornell Hydraulic Laboratory.
		1.5035	0.5285	3.377	2.00	0.70	
		1.4631	0.5221	3.327	0.70	0.40	
		1.3978	0.4960	3.133	0.40	0.11	
5	6.65	1.5671	0.5101	3.237	5.00	2.00	Application of Bazin's Formula by Professor Williams.
		1.5070	0.5282	3.374	2.00	0.70	
		1.4675	0.5221	3.327	0.70	0.40	
		1.3595	0.4790	3.013	0.40	0.16	
6	6.55	1.4886	0.5294	3.384	0.70	0.40	Weir No. 2, University of Utah Hydraulic Laboratory.
		1.4632	0.5192	3.305	0.40	0.20	
7	6.55	1.5175	0.5282	3.374	2.00	0.70	Fteley and Stearns.
		1.5024	0.5260	3.357	0.70	0.40	
8	4.60	1.5032	0.5257	3.355	1.00	0.70	J. B. Francis.
8A		1.4964	0.5214	3.322	1.00	0.70	J. B. Francis.
9	3.72	1.5123	0.5358	3.434	1.15	0.70	Bazin.
		1.4896	0.5324	3.407	0.70	0.40	
		1.4749	0.5265	3.361	0.40	0.18	
10	3.72	1.5101	0.5356	3.432	1.40	0.70	Bazin.
		1.5024	0.5343	3.422	0.70	0.40	
		1.4537	0.5150	3.273	0.40	0.18	
11	3.72	1.5058	0.5240	3.342	1.40	0.70	Weir No. 1, University of Utah Hydraulic Laboratory.
		1.5019	0.5232	3.336	0.70.	0.40	
		1.4549	0.5042	3.193	0.40	0.13	
12	3.65	1.5133	0.5263	3.360	1.75	0.70	Cornell Hyd. Lab.
13	3.56	1.5118	0.5277	3.371	0.90	0.70	Fteley and Stearns.
		1.5029	0.5262	3.351	0.70	0.40	
		1.4784	0.5165	3.285	0.40	0.14	
14	3.31	1.5209	0.5365	3.440	2.00	0.70	Bazin.
		1.4860	0.5311	3.397	0.70	0.40	
		1.4612	0.5212	3.320	0.40	0.18	
15	3.17	1.5348	0.5421	3.484	0.90	0.70	Fteley and Stearns.
		1.5225	0.5402	3.469	0.70	0.40	
		1.4627	0.5162	3.282	0.40	0.10	
16	2.60	1.5075	0.5286	3.378	1.00	0.70	Fteley and Stearns.
		1.4980	0.5271	3.366	0.70	0.40	
		1.4998	0.5279	3.372	0.40	0.25	
17	2.47	1.5621	0.5534	3.495	1.40	0.70	Bazin.
		1.5056	0.5447	3.505	0.70	0.40	
18	2.47	1.5402	0.5456	3.512	1.60	0.70	Bazin.
		1.5074	0.5406	3.472	0.70	0.40	
19	2.23	1.5472	0.5374	3.447	1.60	0.70	Cornell Hyd. Lab.
20	1.70	1.5409	0.5417	3.481	1.00	0.70	Fteley and Stearns.
		1.5169	0.5381	3.452	0.70	0.40	
		1.5026	0.5323	3.406	0.40	0.18	

TABLE C.—(*Continued.*)

(1) No. of table.	(2) Height of weir.	(3) n.	(4) Log. m.	(5) m.	(6) Limits of Head, in Feet. Upper.	(7) Lower.	(8) Name of experimenter.
21	1.64	1.5938	0.5636	3.661	1.40	0.70	Bazin.
		1.5179	0.5519	3.564	0.70	0.40	
		1.4775	0.5357	3.433	0.40	0.28	
22	1.64	1.5716	0.5575	3.610	1.50	0.70	Bazin.
		1.5281	0.5505	3.552	0.70	0.40	
		1.5000	0.5397	3.465	0.40	0.32	
23	1.64	1.5338	0.5608	3.637	0.70	0.40	Weir No. 3. University of Utah Hydraulic Laboratory.
		1.5000	0.5473	3.526	0.40	0.12	
24	1.16	1.5985	0.5780	3.784	1.00	0.70	Bazin.
		1.5595	0.5719	3.732	0.70	0.40	
		1.5025	0.5490	3.459	0.40	0.28	
25	1.14	1.6155	0.5720	3.733	1.40	0.70	Bazin.
		1.5350	0.5595	3.627	0.70	0.40	
		1.5181	0.5526	3.569	0.40	0.28	
26	1.00	1.6149	0.5732	3.743	0.90	0.70	Fteley and Stearns.
		1.5525	0.5635	3.660	0.70	0.40	
		1.5250	0.5524	3.568	0.40	0.18	
27	0.79	1.6389	0.5894	3.885	1.40	0.70	Bazin.
		1.5691	0.5789	3.792	0.70	0.40	
		1.5373	0.5661	3.682	0.40	0.28	
28	0.50	1.7088	0.6265	4.232	0.90	0.70	Fteley and Stearns.
		1.6112	0.6111	4.084	0.70	0.40	
		1.5668	0.5933	3.920	0.40	0.18	

right line is drawn. The points in the left-hand portion of the figure, through which two broken lines are drawn, show the results obtained when a correction is made for velocity of approach.

(*c*).—*Fteley and Stearns Experiments.*—The Fteley and Stearns experiments and the results of computations made on them are given in Tables 7, 13, 15, 16, 20, 26, and 28, and the plottings showing the trial equation, the adopted equations, the results of the final diagram, and the degree of accuracy with which these fit the original experiments, are on Figs. 7, 13, 15, and 16, of Plate LXXXVI*a*, and Figs. 20, 26, and 28, of Plate LXXXVI*b*. The curves of these equations are brought together on Plates LXXXVII and LXXXVIII, where they, with others, are plotted on the same axes, for purposes of comparison.

The heads on the Fteley and Stearns weirs, of heights 3.56, 2.60, 1.70, 1.00, and 0.50 ft., were measured with a device similar to that used by Mr. Francis, or similar to the Cornell 6-ft. Francis piezometer,* and therefore no correction has been applied to them.

* *Transactions*, Am. Soc. C. E., Vol. XII, p. 9.

TABLE D.—BROAD-CRESTED WEIRS.

Values of m and n to be used in the equation, $Q = m\ h^n$, for computing the discharge, in cubic feet per second per foot of length, and the limiting values of the heads to be used in the corresponding equations.

(1) No. of table.	(2) Width of crest.	(3) n.	(4) Log. m.	(5) m.	(6) Limits of Head, in Feet. Upper.	(7) Lower.	(8) Cornell model.
38	5¾ in.	1.5053	0.5223	3.329	2.00	0.81	XL
		1.7428	0.5445	3.503	0.81	0.36	
		1.4285	0.4055	2.544	0.36	0.12	
39	11⅛ in.	1.5097	0.5207	3.317	2.95	1.72	XLVII
		1.6837	0.4797	3.018	0.70	0.70	
		1.6210	0.4698	2.950	0.40	0.40	
40	19¾ in.	1.5381	0.5076	3.218	4.00	3.00	XLI
		1.6943	0.4402	2.756	3.00	0.74	
		1.4224	0.4072	2.554	0.74	0.11	
41	3.17 ft.	1.6505	0.3925	2.469	3.10	1.50	XLVI
		1.4746	0.4246	2.658	1.50	0.50	
42	5.85 ft.	1.4900	0.4234	2.651	2.00	0.70	XLV
		1.4338	0.4155	2.603	0.70	0.50	
43	8.96 ft.	1.4913	0.4245	2.658	3.10	0.70	XLIV
		1.4306	0.4150	2.600	0.70	0.50	
44	12.25 ft.	1.6006	0.3696	2.342	5.00	3.00	XLII
		1.4590	0.4369	2.735	3.00	1.05	
		1.5237	0.4357	2.727	1.05	0.17	
45	16.29 ft.	1.5305	0.4078	2.557	4.50	2.50	XLIII
		1.4797	0.4276	2.677	2.50	0.70	
46	16.29 ft.	1.5561	0.4301	2.692	1.00	0.76	XLIII*a*
		1.4530	0.4178	2.617	0.76	0.16	

During each series of experiments on these weirs* the quantity of water flowing was kept constant; and as one of these (that with height 3.56 ft.) was the standard weir,† the quantity discharged in each series has been computed by using the heads on this weir, in the formula,

$$Q = m\ h^{1.4927}, \text{ in which log. } m = 0.5239.$$

How well this formula fits the experiments made for rating this weir is shown by the heavy broken line in Fig. 13, Plate LXXXVI*a*. For a head of 0.151 ft., the computed discharge is 1.01% too small, according to the one experiment with this low head; and, for the highest head used, namely, 0.805 ft., the computed discharge is 0.48% too small. For heads between these limits, the formula gives some discharges a little more than 0.4% too large.

* *Transactions,* Am. Soc. C. E., Vol. XII, p. 54.

† *Transactions,* Am. Soc. C. E., Vol. XII, p. 110.

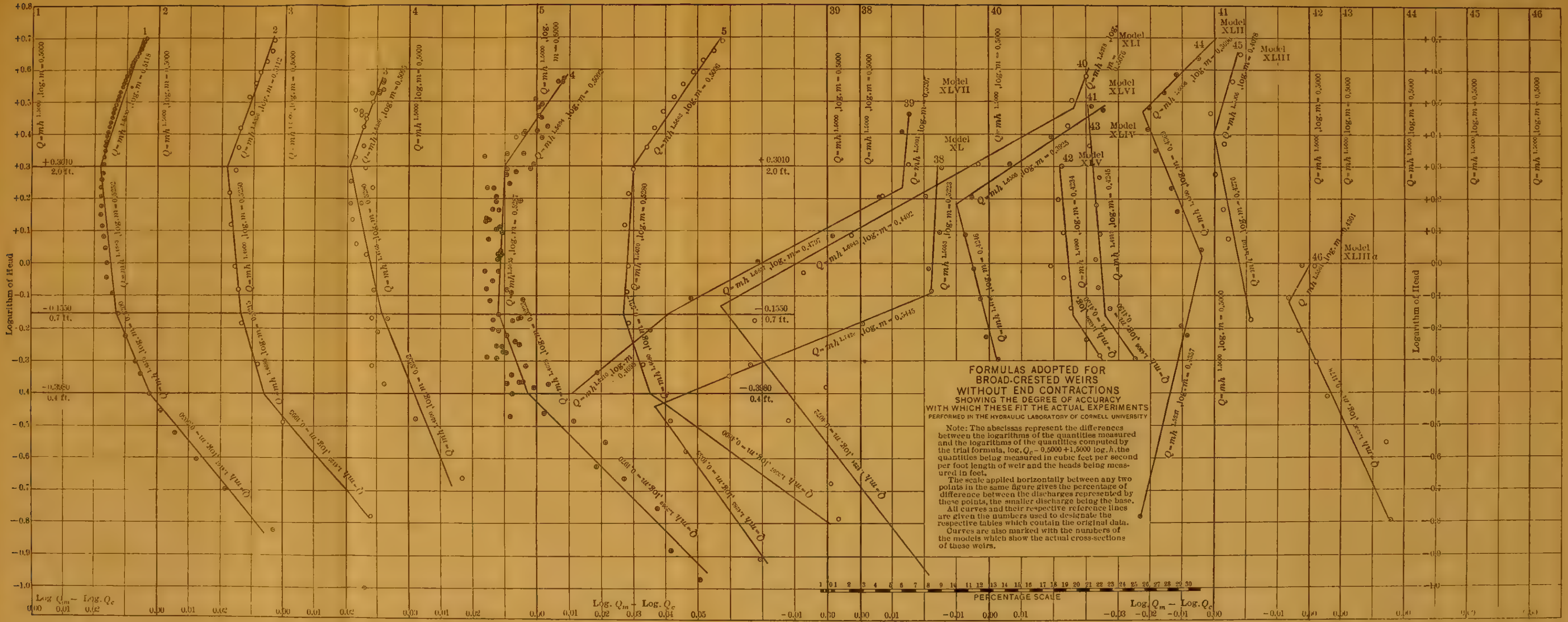

FORMULAS ADOPTED FOR
BROAD-CRESTED WEIRS
WITHOUT END CONTRACTIONS
SHOWING THE DEGREE OF ACCURACY
WITH WHICH THESE FIT THE ACTUAL EXPERIMENTS
PERFORMED IN THE HYDRAULIC LABORATORY OF CORNELL UNIVERSITY
Note: The abscissas represent the differences between the logarithms of the quantities measured and the logarithms of the quantities computed by the trial formula, log. Q_c - 0.5000 + 1.5000 log. h, the quantities being measured in cubic feet per second per foot length of weir and the heads being measured in feet.
The scale applied horizontally between any two points in the same figure gives the percentage of difference between the discharges represented by these points, the smaller discharge being the base.
All curves and their respective reference lines are given the numbers used to designate the respective tables which contain the original data.
Curves are also marked with the numbers of the models which show the actual cross-sections of these weirs.
Logarithm of Head
PERCENTAGE SCALE
Log. Q_m - Log. Q_c
+0.3010
2.0 ft.
-0.1550
0.7 ft.
-0.3980
0.4 ft.
Model XLVII
Model XL
Model XLI
Model XLVI
Model XLIV
Model XLV
Model XLII
Model XLIII
Model XLIII a

TABLE E.—IRREGULAR-CRESTED WEIRS OF RIGHT-LINE SECTIONS.

Values of m and n to be used in the equation, $Q = m\ h^n$, for computing the discharge, in cubic feet per second per foot of length, and the limiting values of the heads to be used in the corresponding equations.

(1) No. of table.	(2) n.	(3) Log. m.	(4) m.	(5) Limits of Head, in Feet. Upper.	(6) Lower.	(7) Cornell model.	(8) Dam on weir.
12	1.4978	0.5278	3.371	1.80	0.80	XXI	
47	1.4848	0.5393	3.462	4.00	0.32	XI	
48	1.4479	0.5704	3.719	2.00	0.85	XXII	Cambria.
	1.5912	0.5815	3.815	0.85	0.40		
49	1.5592	0.5570	3.606	2.80	2.00	XXVI	Cambria.
	1.4986	0.5753	3.761	2.00	1.10		
50	1.5472	0.5556	3.594	2.80	1.60	XXIII	Cambria.
	1.5083	0.5633	3.658	1.60	0.40		
51	1.5576	0.5553	3.592	2.80	1.35	XXIV	Cambria.
52	1.5260	0.5640	3.664	1.40	0.32	XXV	Cambria.
53	1.6705	0.4685	2.941	4.00	1.90	XXVII	Lawrence.
	1.5180	0.4972	3.142	1.90	0.32		
54	1.5278	0.5422	3.485	1.00	0.40	XX	
55	1.6311	0.4625	2.901	3.65	1.60	XXVII	Lawrence.
	1.4920	0.4901	3.091	1.60	0.63		
	1.4507	0.4819	3.033	0.63	0.28		
65	1.5365	0.5550	3.589	4.00	1.00	L	
	1.4558	0.5550	3.589	1.00	0.35		
66	1.5343	0.5563	3.600	4.00	1.00	LI	
	1.6363	0.5563	3.600	1.00	0.28		

However, as 0.944 ft. is the highest and 0.188 ft. the lowest head used in calculating these discharges, and as neither of these gives a discharge differing more than 0.5% from that actually measured volumetrically; and, further, as the results obtained by Bazin, when experimenting on the same weirs at different times, differ by percentages much greater than this, it is not deemed necessary to repeat this work, using the formulas adopted for this weir instead of that above given.

As a matter of fact, the discharges for all the runs over the Fteley and Stearns weirs had been computed by the formula, $q = m\ h^{1.4927}$, in which log. m = 0.5239, or m = 3.341, and these results were thought to be very satisfactory until the present method of determining equations had been discovered.

The heads on the Fteley and Stearns weir of height 3.17 ft., and having a length of 5.00 ft.,* were measured with a piezometer which took the water pressure from near the bottom of the canal 6 ft. up stream from the weir.†

* *Transactions*, Am. Soc. C. E., Vol. XII, p. 56.

† *Transactions*, Am. Soc. C. E., Vol. XII, p. 53.

TABLE F.—IRREGULAR-CRESTED WEIRS OF RIGHT-LINE AND CURVED SECTIONS.

Values of m and n to be used in the equation, $Q = m\,h^n$, for computing the discharge, in cubic feet per second per foot of length, and the limiting values of the heads to be used in the corresponding equations.

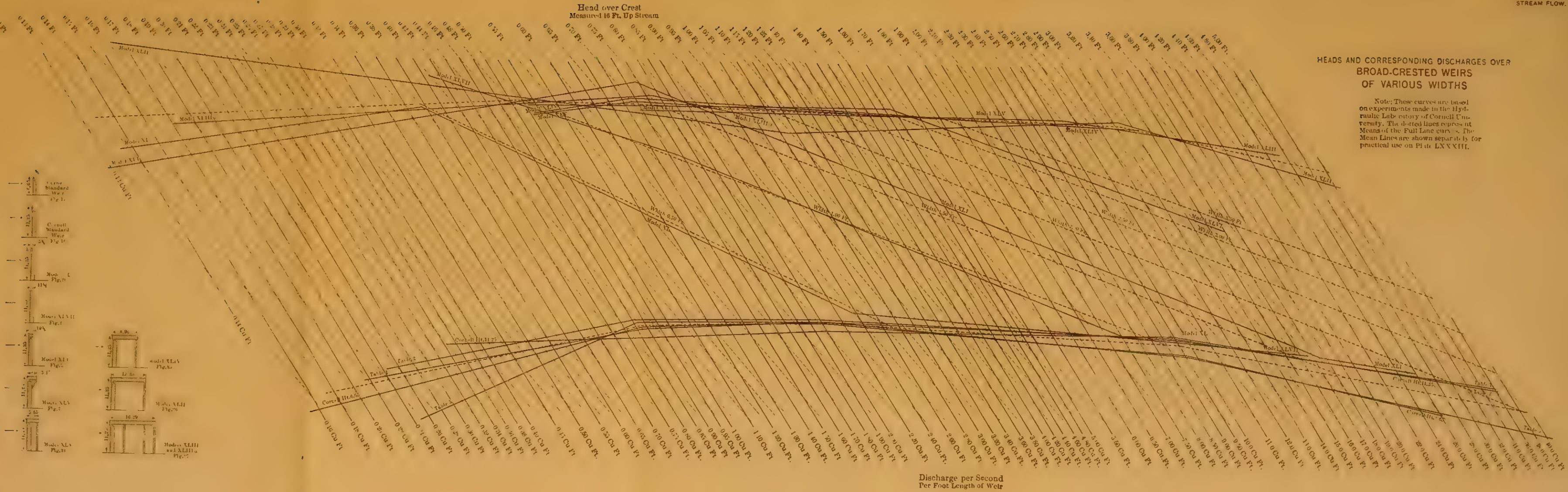
(1) No. of table.	(2) n.	(3) Log. m.	(4) m.	(5) Limits of Head, in Feet. Upper.	(6) Lower.	(7) Cornell model.	(8) Dam on weir.
56	1.5217	0.4790	3.013	1.40	0.56	Francis model.	Lawrence.
57	1.5322	0.5310	3.396	3.20	0.40	XXX	Plattsburg.
58	1.5716	0.5451	3.508	2.80	0.56	XXXIII	Plattsburg.
59	1.6226	0.5398	3.466	3.20	0.63	XXXIV	Plattsburg.
60	1.6063	0.5163	3.283	4.00	0.48	XXXV	Chambly.
	1.4576	0.4846	3.052	0.48	0.08		
61	1.5941	0.5217	3.324	2.80	1.25	XXXVI	Chambly.
	1.5555	0.5255	3.354	1.25	0.48		
62	1.4074	0.5736	3.746	3.55	1.60	XXXVIII	Dolgeville.
	1.5752	0.5401	3.468	1.60	0.40		
63	1.4425	0.5546	3.586	4.00	1.25	XXXIX	Dolgeville.
	1.5081	0.5481	3.533	1.25	0.40		
64	1.5220	0.5570	3.606	3.20	1.25	XLVIII	
	1.4818	0.5609	3.638	1.25	0.50		
65	1.5365	0.5550	3.589	4.00	1.00	L	
	1.4558	0.5550	3.589	1.00	0.35		
67	1.5180	0.5582	3.616	3.30	0.63	XLIX	

The Cornell float piezometer was designed to duplicate this device used for measuring heads by Fteley and Stearns; therefore, the corrections necessary to reduce heads thus measured to equivalent 15-ft. tape readings, as shown on Plate XCIII, have been applied, except that for heads of less than 1 ft. the correction has been made to decrease uniformly from 0.007 for a 1-ft. head to 0 at the origin.

(*d*).—*Bazin Experiments.*—The results of Bazin's experiments,* Series 1 to 10, inclusive, and of computations made on them, are given in Tables 9, 10, 14, 17, 18, 21, 22, 24, 25, and 27, and the plottings showing the trial equation, the adopted equations, the results of the final diagram, and the degree of accuracy with which these fit the original experiments, are shown in Figs. 9, 10, 14, of Plate LXXXVI*a*, and Figs. 17, 18, 21, 22, 24, 25, and 27 of Plate LXXXVI*b*.

The curves of these equations are brought together on Plates LXXXVII and LXXXVIII, where they, with others of this class, are plotted on the same axes, for purposes of comparison.

* Experiments by M. Bazin, Inspector-General of Bridges and Highways, published in *Annales des Ponts et Chaussées*, October, 1888, and January, 1890. Translated by Arthur Marichal and John C. Trautwine, Jr., and published in Volumes VII, IX, and X, *Proceedings*, Engineers' Club of Philadelphia.



HEADS AND CORRESPONDING DISCHARGES OVER BROAD-CRESTED WEIRS OF VARIOUS WIDTHS

Note: These curves are based on experiments made in the Hydraulic Laboratory of Cornell University. The dotted lines represent Means of the Full Line curves. The Mean Lines are shown separately for practical use on Plate LXXXIII.

The method used by Bazin for measuring heads is described on pages 1585 and 1586. The heads, as originally measured, have been reduced to equivalent 15-ft. tape readings by applying to them the necessary corrections, as shown on Plate XCIII. The heads, as originally measured, and the equivalent tape readings, are given in the above-named tables.

The quantities of discharge, for Bazin's Series 1, 2, and 3, are taken from the tabulation of his experiments, but he does not give the quantities of discharge for the other seven series; therefore, for the purpose of determining these quantities, the curve shown on Plate XCIV was constructed by using the heads, in meters, as ordinates and the quantities of discharge, in cubic feet per second per foot of length of weir, as abscissas.

The points plotted were determined by using the heads and quantities given in Bazin's Series 1 and 2. These two series contain all the experiments made on Bazin's standard weir.

The quantities of discharge for Series 1 and 2 were measured volumetrically, as were also those for Series 3. For the remaining seven series, however, only the head on the standard weir is given; and with this quantity, given in meters, by using the curve on Plate XCIV, the discharges, in cubic feet per second per foot of length of weir, were found.

(*e*).—*Cornell Experiments on Sharp-Crested Weirs.*—The Cornell experiments of this class, including Series XXIX, XXIX*a*, XI, and XXI (Figs. 16, 17, 18, and 19), and the results of computations made on them, are given in Tables 3, 4, 12, and 19, and in Figs. 3, 4, and 12, of Plate LXXXVI*a*, and Fig. 19 of Plate LXXXVI*b*.

The curves of these equations are brought together on Plates LXXXVII and LXXXVIII, where they, with others of this class, are plotted on the same axes, for purposes of comparison.

The heads in these experiments were measured with the tapes named in the tables. The experiments in Series XXIX and XXIX*a*, marked *s*, were made in April, 1903; those marked *f* were made in October, 1903. The experiments in Series XI were made in October, 1902; those in Series XXI, in November, 1902.

(*f*).—*Utah Experiments.*—The Utah experiments of this class were made on three weirs: No. 1, 3.72 ft. high and 1.77 ft. long; No. 2, 6.65 ft. high and 6.55 ft. long; and No. 3, 1.64 ft. high and 6.53 ft. long

(see Figs 7, 8, 9, and 13). The water was caught and measured in the concrete measuring basin of the hydraulic laboratory of the University of Utah (Figs. 7, 8, 11, and 13). The heads were measured with the tapes named in the tables. These experiments were made by the students doing work in this laboratory from October, 1907, to May, 1911. The results of the experiments and of computations made on them are shown in Tables 6, 11, and 23, and in Figs. 6 and 11, of Plate LXXXVI*a*, and Fig. 23 of Plate LXXXVI*b*.

The curves of these equations are brought together on Plates LXXXVII and LXXXVIII, where they, with others of this class, are plotted on the same axes, for purposes of comparison.

(*g*).—*Bazin Formula and Cornell Standard Weirs.*—Besides the curves for the foregoing experiments on sharp-crested weirs without end contractions, there are also shown on Plate LXXXVI*a* three curves which give the results obtained by substituting assumed heads in Bazin's formula (see page 1529) for weirs of this class.

Table 1 gives the results Dr. E. W. Schoder, Assoc. M. Am. Soc. C. E., obtained by substituting assumed heads in Bazin's formula for a weir of height 11.25 ft., also some computations on these results. Fig. 1, Plate LXXXVI*a*, gives the trial equation and the adopted equations applied to these results, and shows the degree of accuracy with which they fit.

Tables 2* and 5 give the results Professor Williams obtained by substituting assumed heads in Bazin's formula for weirs of heights 11.25 ft. and 6.65 ft., and some computations on these results.

Figs. 2 and 5, Plate LXXXVI*a*, give the trial equation and the adopted equations applied to these results.

These last two curves are of especial interest. The data which determined them, with the heads, as originally assumed, are the same as those used for constructing the diagrams (page 1587) in the Hydraulic Laboratory of Cornell University; from these diagrams the discharges of these two standard weirs were read.

(2).—For Broad-Crested Weirs.

The broad-crested weirs herein considered were built over the weir at the upper end of the canal in the Hydraulic Laboratory of Cornell University. General cross-sections of these models are shown on Plate

* Tables 2 to 67, inclusive, and Tables A and B are not reproduced herein, but are filed in the Library of the Society.

PLATE XCIa.
PAPERS, AM. SOC. C. E.
SEPTEMBER, 1913.
LYMAN ON
WEIR MEASUREMENT OF
STREAM FLOW.

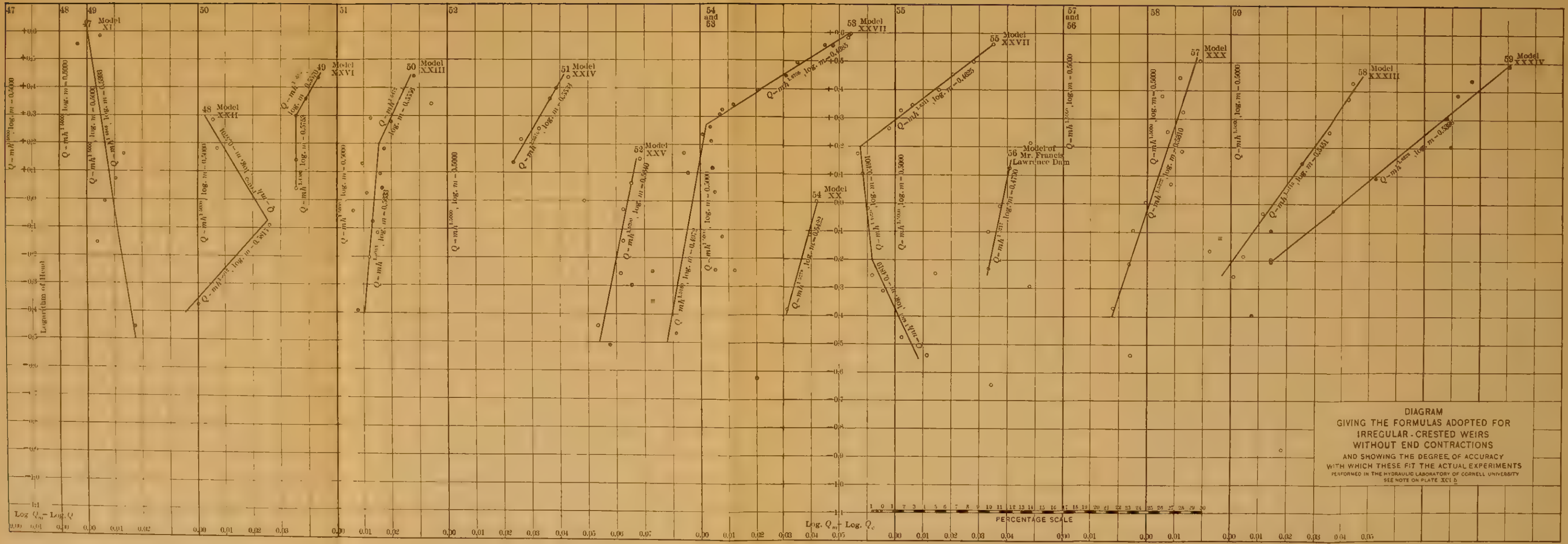
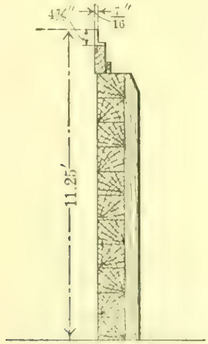


DIAGRAM
GIVING THE FORMULAS ADOPTED FOR
IRREGULAR-CRESTED WEIRS
WITHOUT END CONTRACTIONS
AND SHOWING THE DEGREE OF ACCURACY
WITH WHICH THESE FIT THE ACTUAL EXPERIMENTS
PERFORMED IN THE HYDRAULIC LABORATORY OF CORNELL UNIVERSITY
SEE NOTE ON PLATE XCI b

XC, and detailed drawings are reproduced in Figs. 16, 17, and 20 to 27, inclusive. The water after passing over these models flowed through the canal and was measured by the lower standard weir, of height 6.65 ft. The space under the falling sheet in these experiments was only partly aerated. The experiments were made during June and July, 1903.

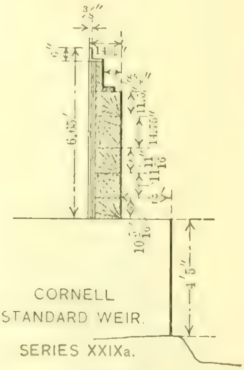
The results of these experiments are given in Tables 1 to 5 and 38 to 46, inclusive, and the plottings showing the trial equation, the adopted equations, the results of the final diagram, and the degree of accuracy attained, are shown on Plate LXXXIX. The curves of these equations are brought together on Plate XC, where they are plotted on the same axes, for the purpose of comparing the results.

The adopted equations for these weirs and the limits of the heads between which each may be applied are given in Table D.



CORNELL STANDARD WEIR.
SERIES XXIX.

FIG. 16.



SERIES XXIXa.

FIG. 17.

(3).—For Irregular Weirs with Cross-Sections of Right Lines.

All the models of weirs of this class were constructed in the Cornell Hydraulic Laboratory, at the lower end of the canal, over the weir of height 6.65 ft., and the water flowing over them was measured by the upper weir, of height 11.25 ft. General cross-sections of these models are shown on Plate LXXXIV, and detailed drawings are reproduced in Figs. 17 to 19, 28 to 34, inclusive, 43 and 44. The results of these experiments are given in Tables 3, 4, 12, 37 to 55, inclusive, and also 65 and 66. The plottings giving both the trial equation and the adopted equations and showing their accuracy are shown on Plates XCI*a* and XCI*b*. The curves of these equations are brought together,

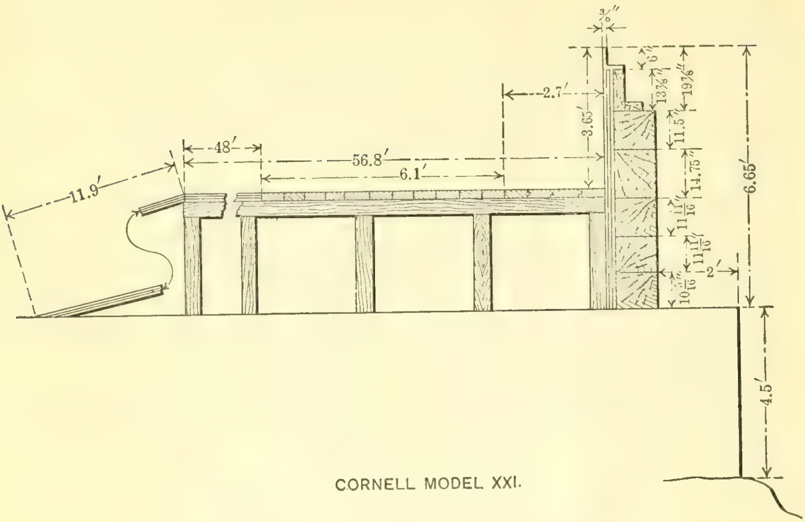


FIG. 18.

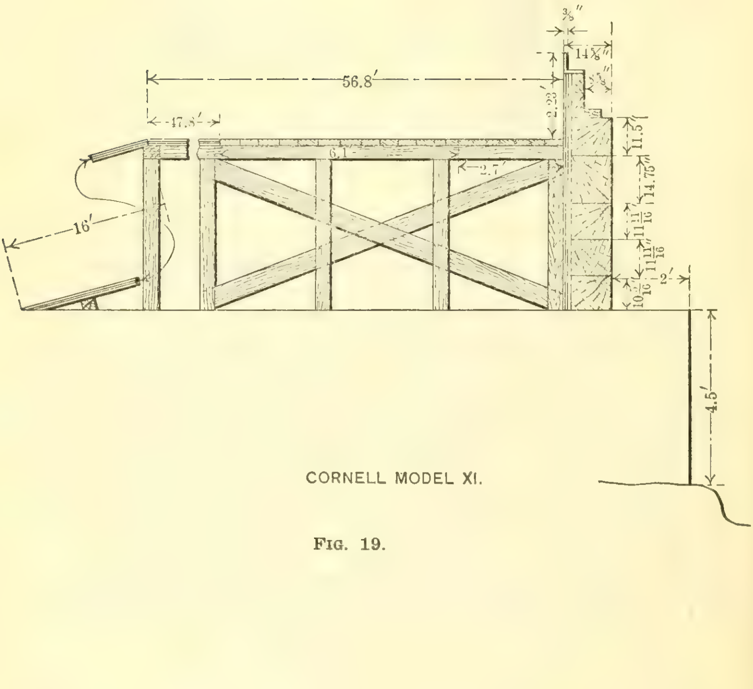


FIG. 19.

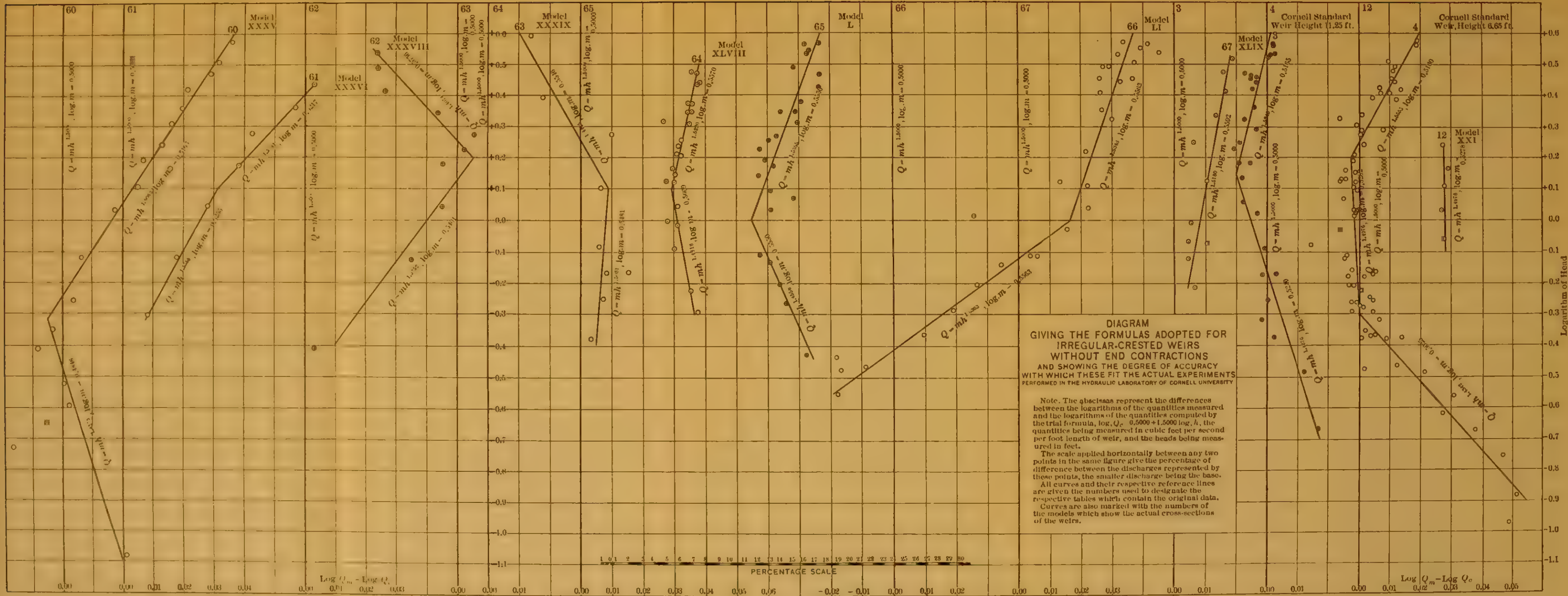
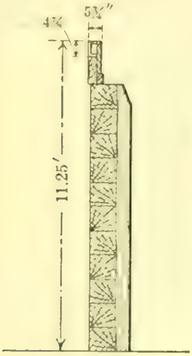


DIAGRAM
GIVING THE FORMULAS ADOPTED FOR
IRREGULAR-CRESTED WEIRS
WITHOUT END CONTRACTIONS
AND SHOWING THE DEGREE OF ACCURACY
WITH WHICH THESE FIT THE ACTUAL EXPERIMENTS
PERFORMED IN THE HYDRAULIC LABORATORY OF CORNELL UNIVERSITY
Note. The abscissas represent the differences between the logarithms of the quantities measured and the logarithms of the quantities computed by the trial formula, log. Q_c = 0.5000 + 1.5000 log. h, the quantities being measured in cubic feet per second per foot length of weir, and the heads being measured in feet.
The scale applied horizontally between any two points in the same figure give the percentage of difference between the discharges represented by these points, the smaller discharge being the base.
All curves and their respective reference lines are given the numbers used to designate the respective tables which contain the original data.
Curves are also marked with the numbers of the models which show the actual cross-sections of the weirs.
Model XXXV
Model XXXVI
Model XXXVIII
Model XXXIX
Model XLVIII
Model L
Model LI
Model XLIX
Cornell Standard Weir Height 11.25 ft.
Cornell Standard Weir, Height 6.65 ft.
Model XXI
PERCENTAGE SCALE
Log Q_m − Log Q_c
Logarithm of Head

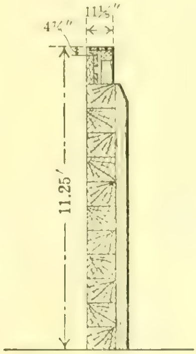
with others of a similar character, on Plate LXXXIV, where, for purposes of comparison, they are plotted on the same axes. The experiments of Series XX and also those of Series XXII, XXIII, XXIV, and XXVI were made in November, 1902. Three of the runs or experiments of Series XXVII were made in December, 1902, the others in April, 1903.

In Series XXIV, XXV, and XXVI there was no aeration behind the falling sheet, but in the other series a free access of air was provided.

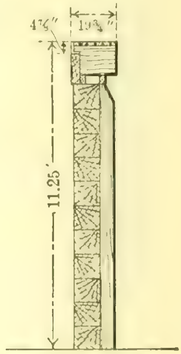
The adopted equations for these weirs and the limits of the heads between which they may be applied are given in Table E.



CORNELL MODEL XL.
FIG. 20.



CORNELL MODEL XLVII.
FIG. 21.



CORNELL MODEL XLI.
FIG. 22.

(4).—For Irregular Weirs with Cross-Sections of Right Lines and Curves.

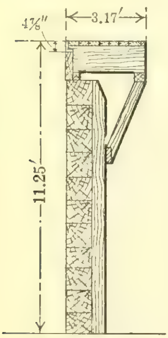
Most of the models of the weirs and dams of this class were built in the Cornell Laboratory over the high weir at the upper end of the canal. General cross-sections of these models are shown on Plate LXXXV, and detailed drawings are reproduced in Figs. 16, 35 to 43, inclusive, and 45. Provision was made in all cases for a free access of air behind the falling sheet. These experiments were made during May and June, 1903.

The results obtained are given in Tables 56 to 65, inclusive, and in Table 67, and the plottings, with both the trial equation and the adopted equations, also the degree of accuracy attained, are shown on Plates XCIa and XCIb.

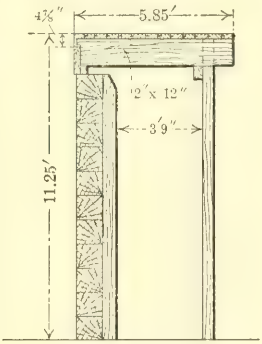
The curves of these equations are brought together on Plate LXXXV. Table F gives the adopted equations for these weirs and the limits of the heads between which each may be applied.

G.—Similarity of the Curves That Represent the Adopted Formulas.

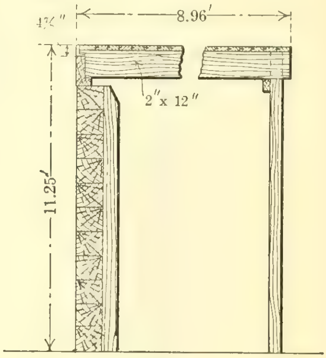
Before taking up a comparison of the discharges over weirs of similar or nearly similar cross-sections, attention will be drawn to Plates LXXXVI*a*, LXXXVI*b*, LXXXIX, XCI*a*, and XCI*b*, on which the adopted equations and their loci for sharp crests, broad crests, and irregular crests, respectively, are shown.



CORNELL MODEL XLVI.
FIG. 23.



CORNELL MODEL XLV.
FIG. 24.

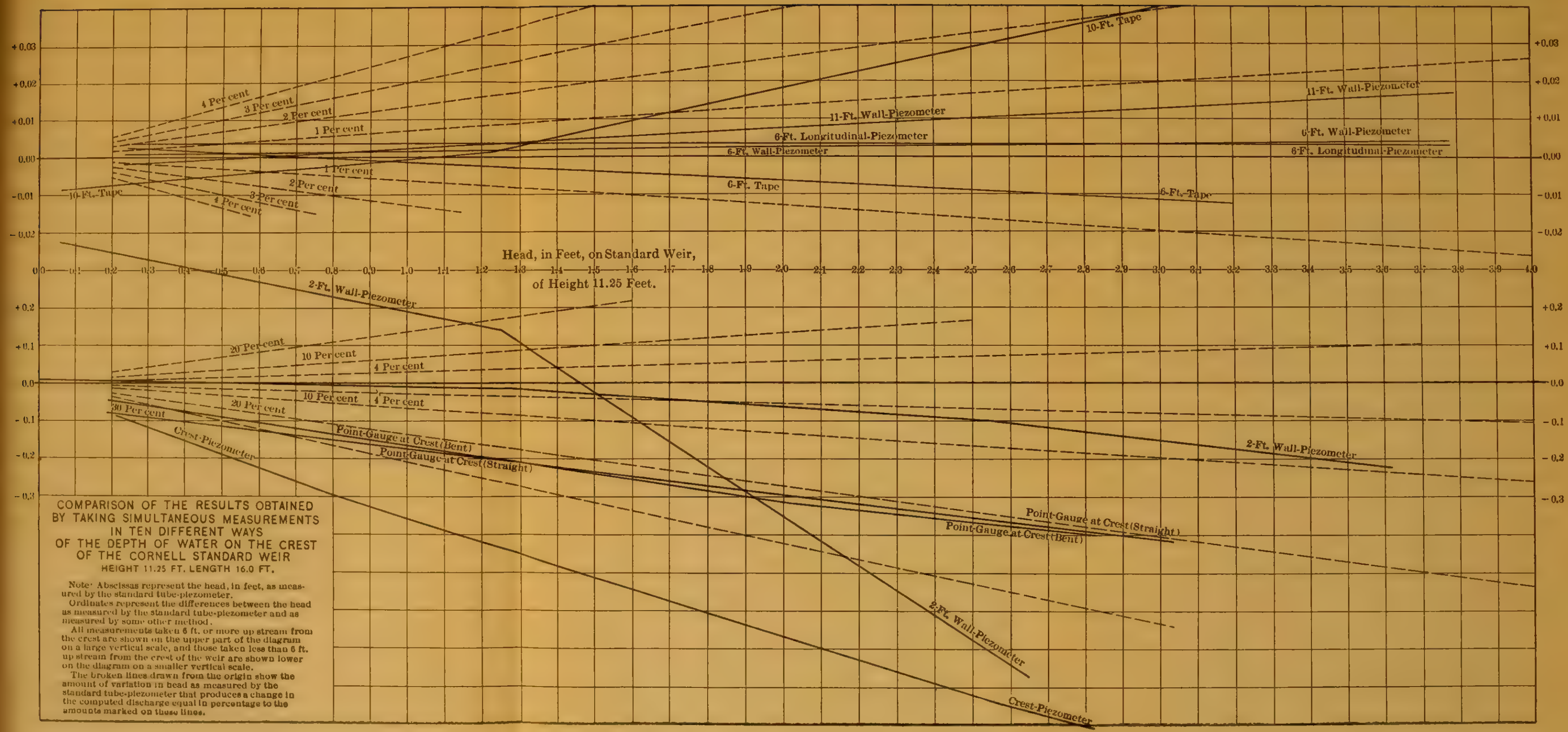


CORNELL MODEL XLIV.
FIG. 25.

(1).—For Sharp Crests—Plates LXXXVI*a* and LXXXVI*b*.

The curves for experiments on sharp-crested weirs without end contractions are shown on Plates LXXXVI*a* and LXXXVI*b*. Although these "curves" are made up of right lines, it would be almost impossible to draw any line of any curvature which would fit these experiments better than do these adopted right lines.

On these plates, as arranged originally, an independent series of right lines was drawn, fitting the experiments with accuracy. These results, however, were not of great value in a general way, as one curve was applicable to only one set of experiments, and the scale on which the plates were made exaggerated the differences and led to confusion. For this reason, it was decided to make the lines or curves intersect in the same horizontal lines. The two lines, log. $h = -0.01550$ and log. $h = -0.3979$, were selected as those on which the lines representing the experiments should be broken. These lines indicate heads



COMPARISON OF THE RESULTS OBTAINED BY TAKING SIMULTANEOUS MEASUREMENTS IN TEN DIFFERENT WAYS OF THE DEPTH OF WATER ON THE CREST OF THE CORNELL STANDARD WEIR

HEIGHT 11.25 FT. LENGTH 16.0 FT.

Note: Abscissas represent the head, in feet, as measured by the standard tube-piezometer.

Ordinates represent the differences between the head as measured by the standard tube-piezometer and as measured by some other method.

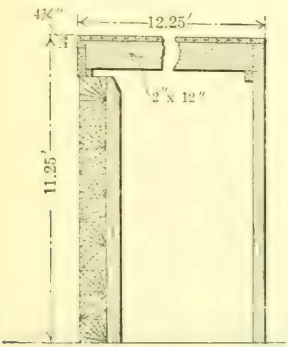
All measurements taken 6 ft. or more up stream from the crest are shown on the upper part of the diagram on a large vertical scale, and those taken less than 6 ft. up stream from the crest of the weir are shown lower on the diagram on a smaller vertical scale.

The broken lines drawn from the origin show the amount of variation in head as measured by the standard tube-piezometer that produces a change in the computed discharge equal in percentage to the amounts marked on these lines.

of 0.70 and 0.40 ft., respectively. It will be observed, however, that in the left-hand portion of Plate LXXXVI*a* five sets of plottings have been divided into four parts, each of which is represented accurately by a straight line. The additional line of division is log. $h = 0.3010$, or $h = 2.00$ ft. These results were easily compared and compiled in a general diagram.

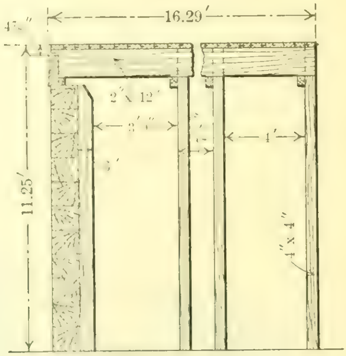
(2).—For Irregular Weirs and Broad-Crested Weirs—Plates LXXXIX, XCI*a*, and XCI*b*.

Although there is not sufficient similarity in the cross-sections of the irregular weirs here shown, or in the results of the experiments on them, to warrant an attempt to devise a general diagram for such structures, there is a similarity in the results obtained from the experiments on broad-crested weirs which naturally produces the general diagram, Plate LXXXIII.



CORNELL MODEL XLII

FIG. 26.



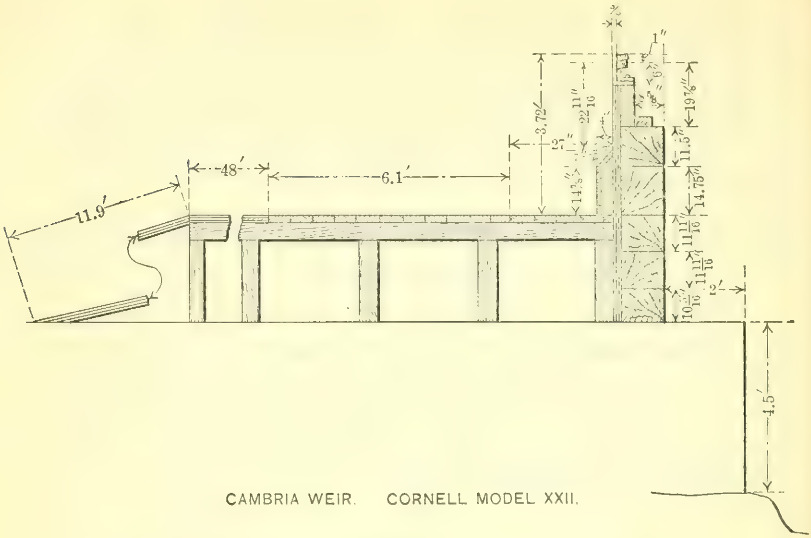
CORNELL MODEL XLIII AND XLIIIa

FIG. 27.

II.—Use of the Scales on Plates LXXXVI a, LXXXVI b, LXXXIX, XCI a, and XCI b, and Method of Constructing Them.

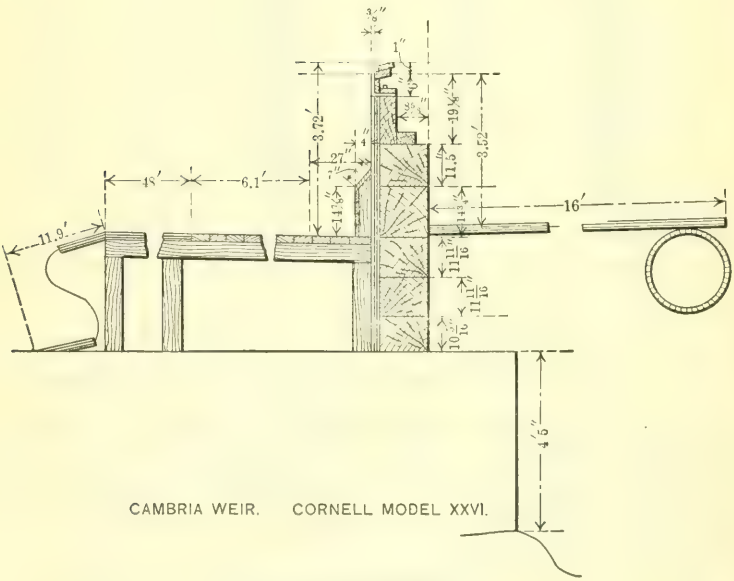
By use of the scales on Plates LXXXVI *a*, LXXXVI *b*, LXXXIX, XCI *a*, and XCI *b*, the method of constructing which is described below, the accuracy with which any particular experiment fits the adopted line or formula can be seen at once, and can be read to the nearest tenth of 1 per cent.

Let log. Q be the logarithm of the discharge represented by any point on the diagram, and let p be any percentage of this discharge,



CAMBRIA WEIR. CORNELL MODEL XXII.

FIG. 28.



CAMBRIA WEIR. CORNELL MODEL XXVI.

FIG. 29.

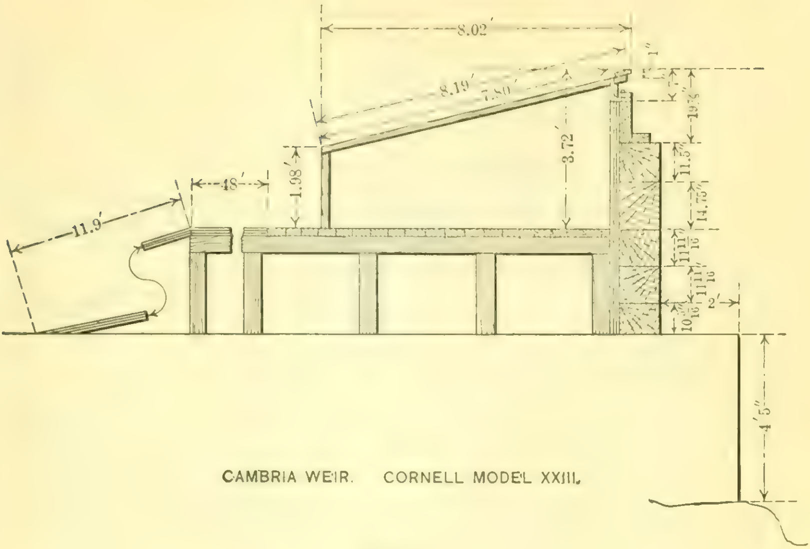

8.02′
8.19′
7.80′
1″
3.72′
1.98′
.48′
11.9′
11.5″
14.75″
2′
4′5″
CAMBRIA WEIR. CORNELL MODEL XXIII.

FIG. 30.

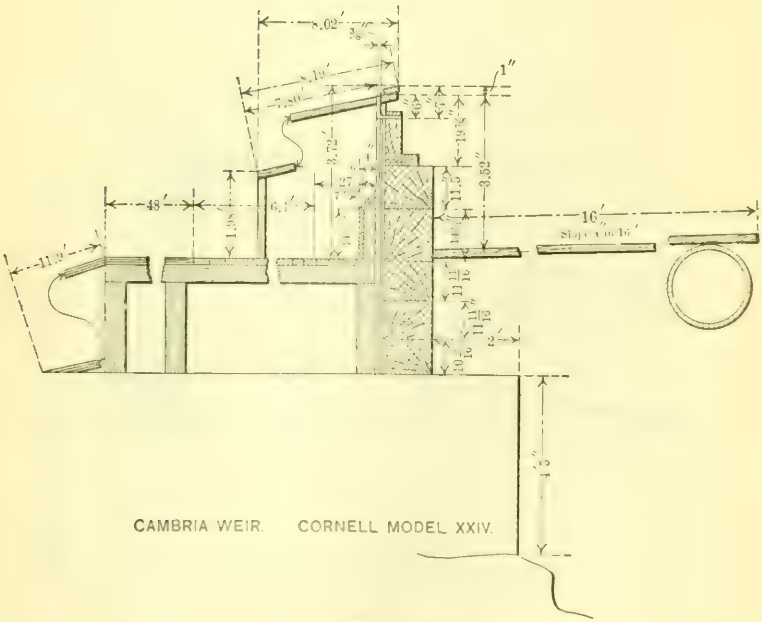

1″
3.72′
3.52″
11.5″
.48′
1.98′
11.9′
16′
2′
CAMBRIA WEIR. CORNELL MODEL XXIV.

FIG. 31.

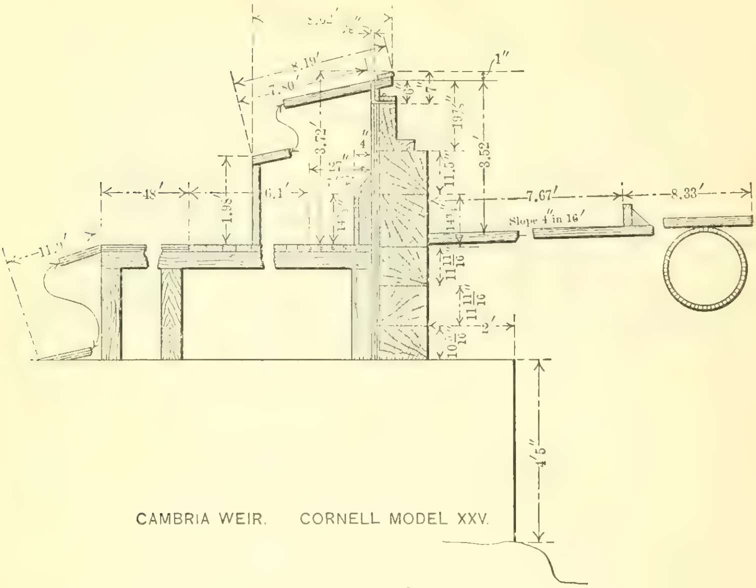

CAMBRIA WEIR. CORNELL MODEL XXV.

FIG. 32.

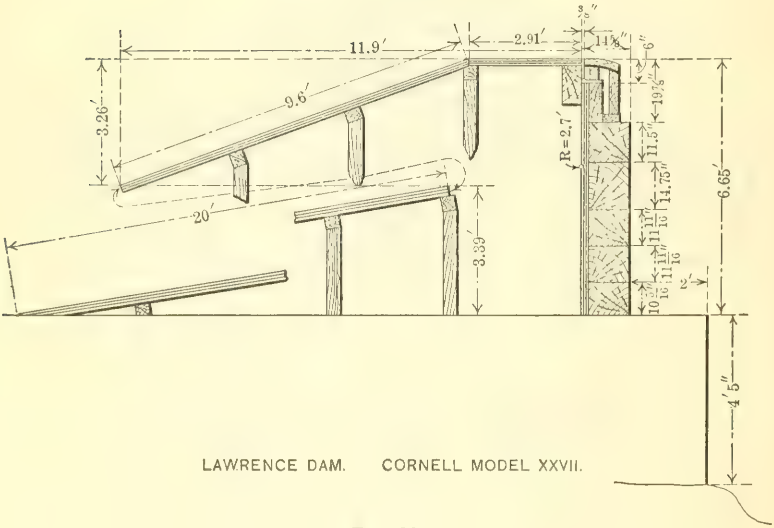
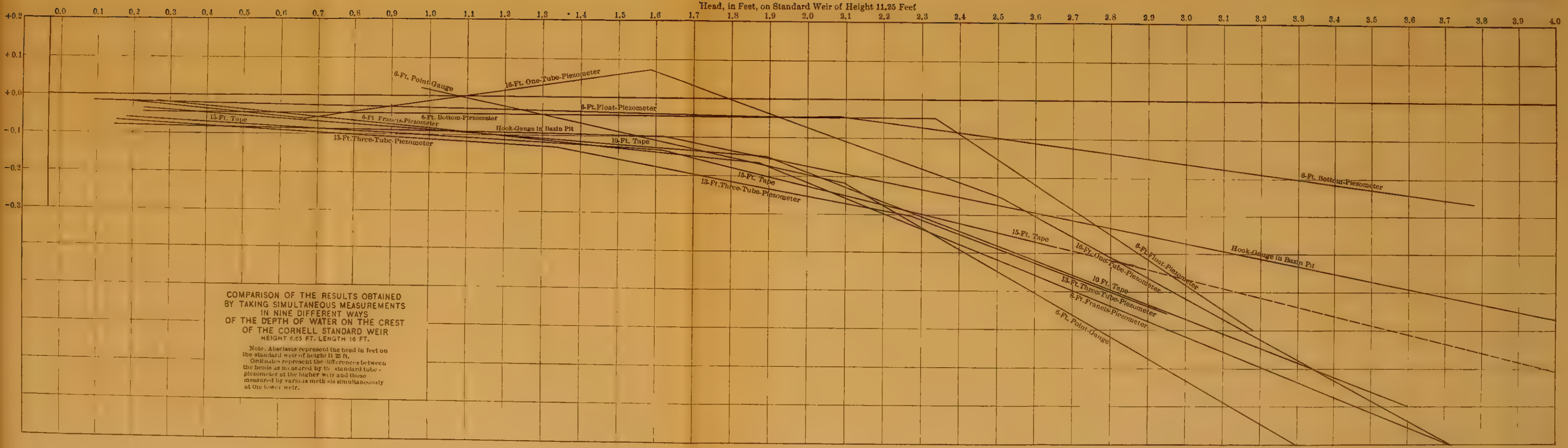

LAWRENCE DAM. CORNELL MODEL XXVII.

FIG. 33.



COMPARISON OF THE RESULTS OBTAINED
BY TAKING SIMULTANEOUS MEASUREMENTS
IN NINE DIFFERENT WAYS
OF THE DEPTH OF WATER ON THE CREST
OF THE CORNELL STANDARD WEIR
HEIGHT 6.65 FT. LENGTH 16 FT.

Note. Abscissas represent the head in feet on the standard weir of height 11.25 ft.

Ordinates represent the differences between the heads as measured by the standard tube-piezometer at the higher weir and those measured by various methods simultaneously at the lower weir.

Q. To find the distance, D, between the points, log. Q and log. $(Q + pQ)$:

$$D = \log.\ (Q + pQ) - \log.\ Q$$
$$= \log.\ [Q\ (1 + p)] - \log.\ Q = \log.\ Q + \log.\ (1 + p) - \log.\ Q$$
$$= \log.\ (1 + p).$$

Therefore, if p is 1%,

$$D = \log.\ 1.01 = 0.0043.$$

If p is 2%,

$$D = \log.\ 1.02 = 0.0086.$$

If p is 3%,

$$D = \log.\ 1.03 = 0.0128, \text{ etc., etc.}$$

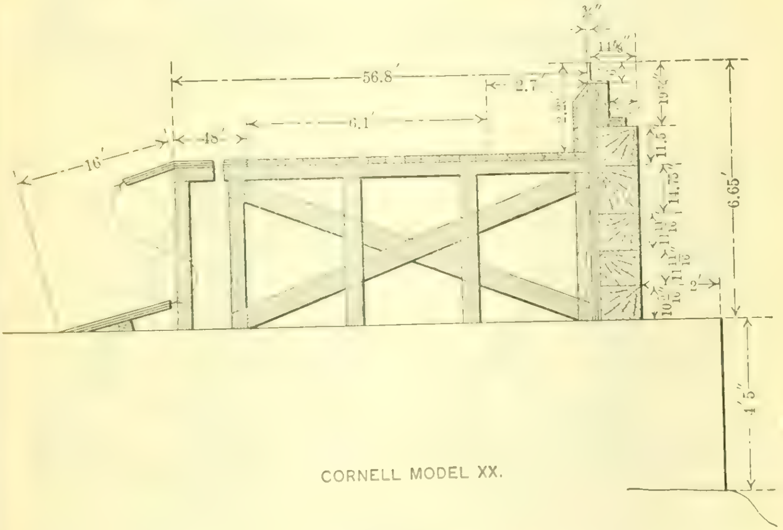


FIG. 34.

These values are plotted to make the scales drawn on each of these plates.

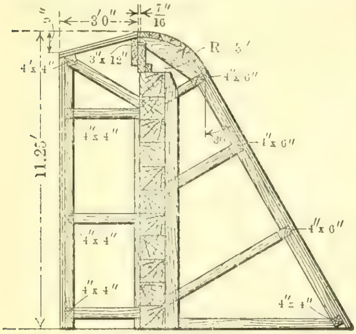
If p is negative, the quantity within the parentheses is less than log. Q, then

$$D = \log.\ Q - \log.\ (Q - pQ),$$

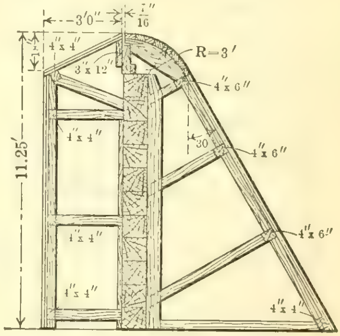
or $D = \log.\ (1 - p)$.

If $p = 1\%$, $D = \log.\ 0.99 = 9.9956 = -\ 0.0044$.
If $p = 2\%$, $D = \log.\ 0.98 = 9.9912 = -\ 0.0088$.
If $p = 3\%$, $D = \log.\ 0.97 = 9.9868 = -\ 0.0132$.

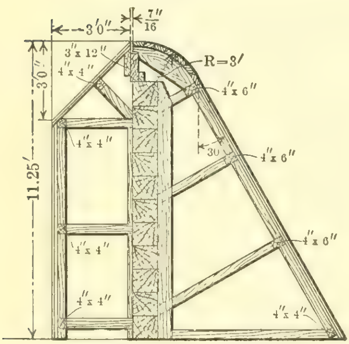
Therefore these scales, which are constructed from positive values of p, will only give correct results, technically, if the smaller quantity of discharge involved is used as the base.



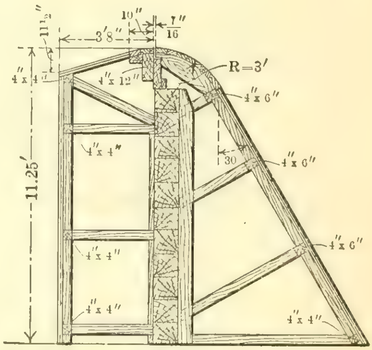
PLATTSBURG DAM.
CORNELL MODEL XXX.
Fig. 35.



PLATTSBURG DAM.
CORNELL MODEL XXXIII.
Fig. 36.



PLATTSBURG DAM.
CORNELL MODEL XXXIV.
Fig. 37.



CHAMBLY DAM.
CORNELL MODEL XXXV.
Fig. 38.

I.—Method of Constructing the Final Diagrams.

(1).—General Statement.

Plates LXXXIV, LXXXV, LXXXVII, LXXXVIII, and XC are designed to show the relation that exists between the discharges of similar weirs.

To put the loci of the adopted equations of similar weirs on the same plate and to refer them to the same axes, it is only necessary to find two points on the locus of each equation and then draw that locus between the two lines that represent the logarithms of the limiting values of h to which the equation is to be applied.

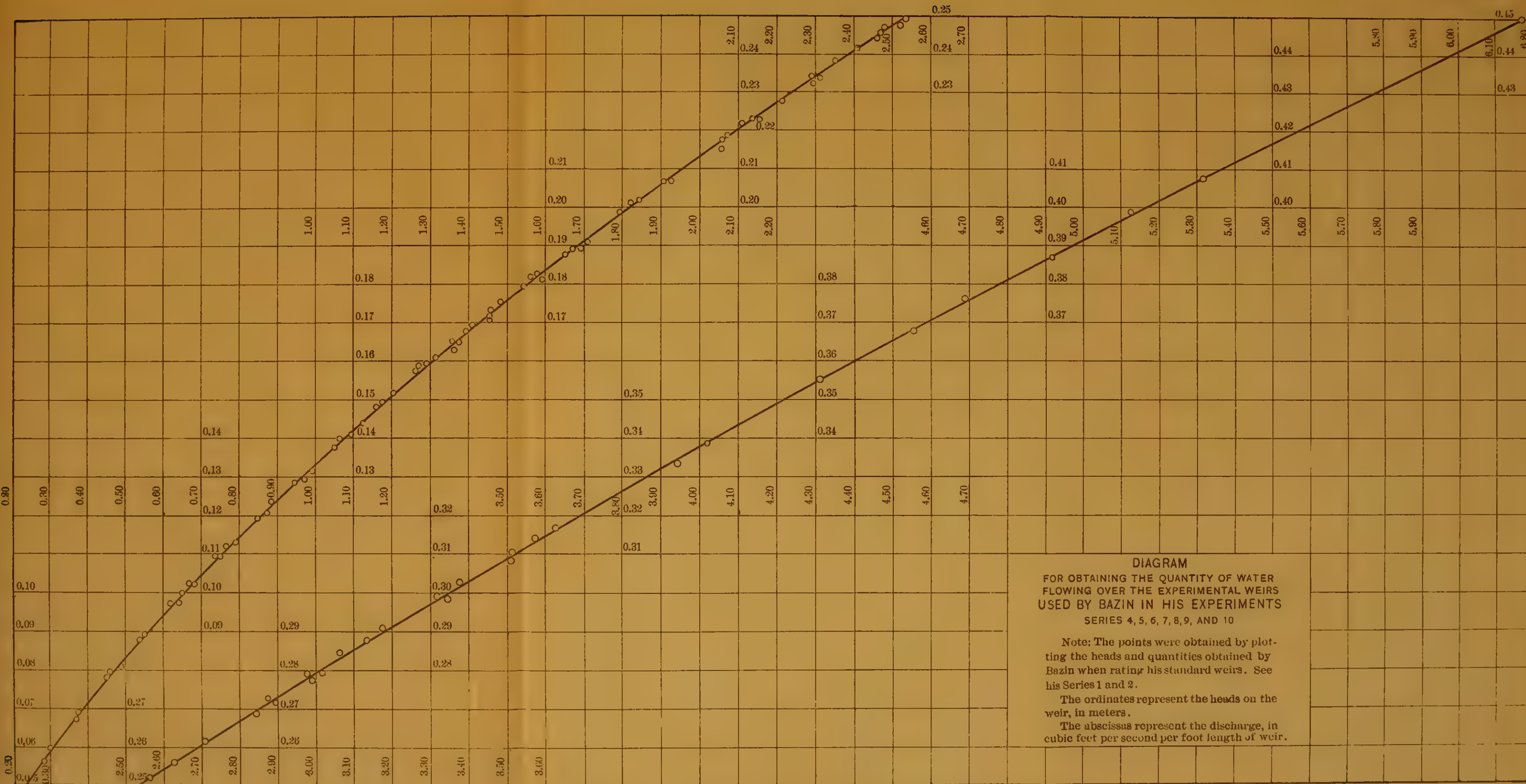


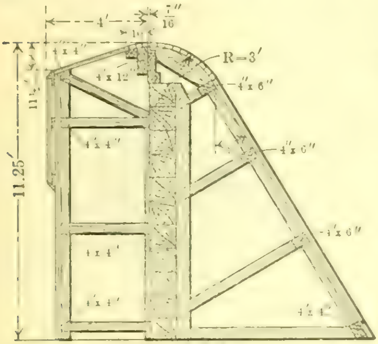
DIAGRAM
FOR OBTAINING THE QUANTITY OF WATER
FLOWING OVER THE EXPERIMENTAL WEIRS
USED BY BAZIN IN HIS EXPERIMENTS
SERIES 4, 5, 6, 7, 8, 9, AND 10

Note: The points were obtained by plotting the heads and quantities obtained by Bazin when rating his standard weirs. See his Series 1 and 2.

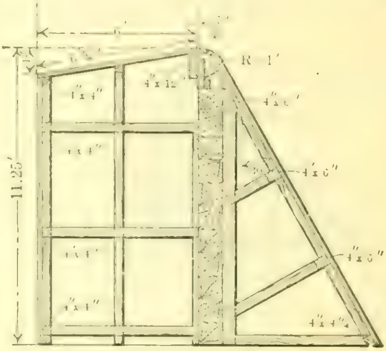
The ordinates represent the heads on the weir, in meters.

The abscissas represent the discharge, in cubic feet per second per foot length of weir.

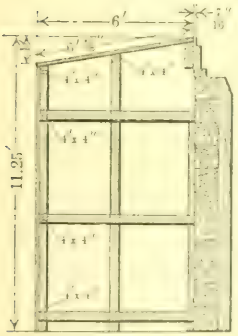
The two lines on which these points can be most easily located are the line, log. $h = 0$, and the line, log. $h = -1$. These two values of log. h, substituted in the equation for which the locus is desired, will give the two values of log. Q which locate the two points sought; but when these two values of log. Q have been found, one may be a plus 0.50 and the other a minus 0.95. If the horizontal scale desired



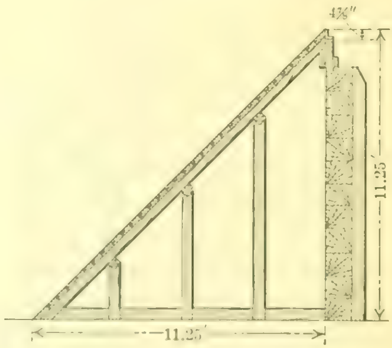
CHAMBLY DAM
CORNELL MODEL XXXVI.
FIG. 39.



DOLGEVILLE DAM.
CORNELL MODEL XXXVIII.
FIG. 40.



DOLGEVILLE DAM
CORNELL MODEL XXXIX.
FIG. 41.



CORNELL MODEL XLVIII.
FIG. 42.

is that used on the original plotting of Plate LXXXVIII, namely, 2 in. for each unit in the second decimal place of the logarithm, the plus 0.50 is 100 in. to the right of the origin and the minus 0.90 is 190 in. to the left of it, thus requiring the drawing to be 290 in. long, in order to contain the part of the locus between the two lines, log. $h = 0$ and log. $h = -1$. If, however, the zero on the line, log. $h = 0$, be brought to the left until the point, plus 0.50, is directly over the minus 0.90,

then the line drawn, instead of making a very small angle with the horizontal, will be vertical, and the line, log. $Q = 0$, will make a small angle with the horizontal.

In this new position the zeros of the two reference lines, log. $h = 0.0000$ and log. $h = -1.0000$, are 290 in. apart horizontally and 10 in. apart vertically, or the tangent of the angle that the line, log. $Q = 0.0000$ makes with the horizontal is $10 \div 290$. As all the

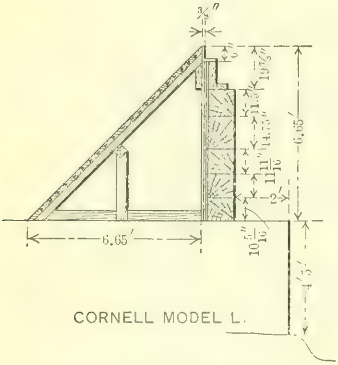


FIG. 43.

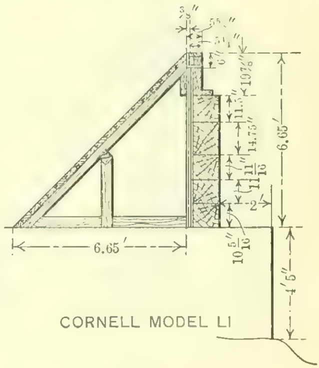


FIG. 44.

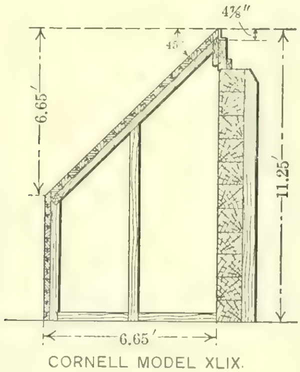


FIG. 45.

log. Q lines are parallel, this is the tangent of the angle which all these lines make with the horizontal. Knowing this angle, if one point on any log. Q line be found, the line can be drawn.

Let the horizontal line, *ab,* in Fig. B, Plate LXXXVI *b,* represent the line, log. $h = 0.00$, and let the horizontal line, *ed,* represent the line, log. $h = -1.00$. The zeros of these two lines are as shown, and the line joining them is the line, log. $Q = 0.0000$. Let *cb* be any

other log. Q line. It is required to locate this line on the drawing. The location of the point, b, is known from the value of the logarithm of the quantity which the line, cb, is to represent; but this point may not fall within the limits of the drawing. However, knowing the tangent of the angle the line makes with the horizontal, and the location of the point, b, in which it intersects the horizontal line, ab, any two points on the line, cb, can be located with the aid of a simple proportion, and the required part of the line can then be drawn. In the same way any number of quantity lines may be constructed.

Lines representing the heads are readily located, as they are drawn horizontally through points on the axis which represent the logarithms of the heads it is desired thus to indicate.

By similar methods, Plates LXXXIV, LXXXV, LXXXVII, and XC have been constructed. The co-ordinates have been placed at a different angle from that used in the construction of Plate LXXXVIII. For Plate LXXXVII, the point, + 0.40, has been placed over — 0.78, so that the zeros are 118 in. apart horizontally. For Plates LXXXIV, LXXXV, and XC, the point, + 0.40, has been placed over — 0.90, so that the zeros are 130 in. apart horizontally.

(2).—For Sharp-Crested Weirs.

(*a*).—*Discharge Over Specific Weirs Used in Experiments.*—The loci of the adopted equations for these weirs are shown on Plates LXXXVI *a* and LXXXVI *b*. The constants in these equations, with the limits of head between which they apply, are given in Table C.

For comparison, the curves are brought together on the same axes on Plates LXXXVII and LXXXVIII, which are identical except for scale and angle of co-ordinates.

It will be seen that these curves are all more or less similar, and that the changes in form, and in position with respect to the locus of the trial equation, are, in general, proportional to the height of the weir.

(*b*).—*Effect of Friction in Channel of Approach.*—How well justified Bazin's assertion is that from the results obtained he could find no difference in the discharge per foot of length of his standard weir of height 3.72 ft., when the length was 6.56 ft. and when the length was 3.28 ft., is shown by the two curves for these weirs. The shorter weir gives the greater discharges for heads near 0.40 ft., and for higher heads the discharges are practically the same.

The small discharges given by Bazin's formula for heads below 0.5 ft. when applied to the Cornell weirs justifies the assertion repeatedly made by Professor Williams that the experiments on these weirs with low heads are not reliable.

(*c*).—*Diagram for Discharge Over Any Weir.*—In order to make a general diagram for weirs of this class, the horizontal distances between the locus of the trial formula (log. $Q = 1.5000$ log. $h + 0.5000$) and the loci of the adopted formulas were read on Plates LXXXVI *a* and LXXXVI*b* on the four lines, log. $h = -0.1000$, log. $h = -0.1550$, log. $h = -0.3979$, and log. $h = -0.7000$.

The two inner of these four lines were selected because, as previously explained, all the curves have been made to intersect in them. The other two were selected as convenient lines, one being near the upper, and the other near the lower, limit of the diagram.

The values thus read were plotted as abscissas and the heights of the weirs as ordinates on Fig. 14. From the curves which these points determine, mean values were taken for weirs of assumed heights.

The values thus obtained were laid off on the four corresponding lines on Plate LXXX as originally constructed on cross-section paper. The locus of the trial equation, of course, was first laid off on the diagram. Only that portion of the original diagram necessary to show the relation existing between the heads, the discharges, and the heights of the weirs, has been reproduced on Plate LXXX; it is a general diagram for measuring the water flowing over all weirs of this class.

Plates LXXXII, LXXXIII, LXXXIV, LXXXV, LXXXVII, and XC are also reproductions of only those portions of the original drawings which are really necessary to show the relation between the quantities named thereon.

(3).—For Broad-Crested Weirs.

On Plate XC are brought together all the curves for broad-crested weirs, the widths varying from $\frac{3}{8}$ in. to 16.29 ft. All these weirs have a height of 11.25 ft. The curves marked Cornell Ht. 6.65 and Table 5 are for weirs of width $\frac{3}{8}$ in. and height 6.65 ft. The weirs with the narrower crests are, for all practical purposes, weirs with sharp crests.

It will be noted that, up to a certain point, that is, up to a certain head, the curves for all these weirs practically coincide; the point at which this coincidence ceases varies with the width of the weir. For

the Cornell Model XL, which has a width of 5¾ in., the curves leave the "broad-crest" line at a head of 0.36 ft. and extend across the diagram diagonally, reaching the "sharp-crest" line at a head of 0.80 ft. This is the head at which the sheet jumps entirely over the "broad crest"; for all greater heads this weir operates as if it had a sharp crest, and its curve, above this point, coincides with that for sharp crests.

As with the weir having a crest 5¾ in. wide, so is it, in a general way, according to this diagram, with those of other widths. The "broad-crest" line is practically parallel to the "sharp-crest" line. The curves for all broad crests follow the "broad-crest" line up to a certain head; then they jump in a straight line diagonally across the diagram to the "sharp-crest" line, and follow it up to the limit of the experiments.

As explained previously, this may be accounted for as follows: As the head increases, a definite point is reached at which a vacuum starts to form under the sheet on top of the crest, with the effect of increasing the flow. This effect is increased until, at a certain head, the sheet jumps entirely free from the crest, and then for all higher heads the weir acts as if the crest were "sharp."

Mean values or lines for the "broad-crest" condition, the "sharp-crest" condition, and the "intermediate" condition, are shown as broken lines on Plate XC; and these form the whole diagram on Plate LXXXIII, which is used for obtaining the discharge over all weirs of this height with broad crests.

Fig. 15, containing the information from which Plate LXXXIII was drawn, shows the relation between the widths of the crests and the heads at which the changes from the broad-crest condition begin, and those at which the sharp-crest condition is reached. From the two curves on this plate, the head can be read at which the broad-crest condition ceases for a crest of any width, within the limits of the experiments, and that also at which the sharp-crest condition begins. From these curves, information was secured for constructing Plate LXXXIII, which is the diagram intended to be used in practice for obtaining the discharge over any weir with a broad crest having a height of 11.25 ft., within the limits shown on this plate.

It might naturally be expected that for some heads the flow over a broad-crested weir would be greater than that over a similar sharp-crested weir, just as the flow through a short tube is greater than

that through a sharp-edged orifice of the same diameter under similar conditions; but the curves on Plate LXXXIII show conclusively that this is not the case for crests wider than 5⅝ in.

This assertion might be made concerning all broad crests, if it were not for the fact that Model XXII gives a greater discharge than Model XXI, the latter having the narrower crest. Notwithstanding this case, it appears that, for weirs with broad crests, the friction on the crest is a more important factor in the discharge than is the tendency of the broad crest to decrease the effect of contraction.

(4).—For Irregular Weirs with Cross-Sections of Right Lines.

The curves for the weirs of this class have been brought together on Plate LXXXIV. The two curves marked XXVII *a* and XXVII *b* are the results of experiments on a model of the Lawrence Dam* built over the upper standard weir in the Hydraulic Laboratory of Cornell University. The curve marked XXVII *a* is the result of plotting the heads as they were measured by the 15-ft. tape. The curve marked XXVII *b* is the result of plotting the heads measured by the 20-ft. tape. It may be that the shape of the dam produced a slight swell in the surface of the water 15 ft. up stream, thus indicating a smaller discharge for the same head than is shown by the 20-ft. tape.

From Plate LXXXV and the plate now under consideration, it appears that very slight differences in models make comparatively large differences in the discharges over them. Observe, for example, the great difference between the two curves, XXI and XXII, on this plate. One is the curve for a weir with a sharp crest and a vertical up-stream face 3.65 ft. high, and the other is the curve for the same weir with the base of the bulkhead thickened 4 in. on the up-stream side for a height of 14⅞ in. from the bottom. The height of this weir was increased 1 in. by timbers attached on the down-stream side of the crest.

For a head of 0.42 ft., Model XXII gives a discharge about 3.6% greater than Model XXI, and for a head of 0.9 ft., it gives a discharge about 7.7% greater.

The constants for the equations for these weirs are given in Table E.

* "Lowell Hydraulic Experiments," p. 136.

(5).—For Irregular Weirs with Cross-Sections of Right Lines and Curves.

The curves for the models of this class are presented on Plate LXXXV. It is interesting to see how uniformly, for high heads, these models give greater discharges than weirs with sharp crests, and that the opposite is true for low heads. Model XXXIV is an extreme example. Its discharge is greater than that of the sharp-crested weir by more than 17% for a head of 3 ft. and, for a head of 0.65 ft., the discharge is about 3.3% smaller. The two curves, XXXV and XXXVI, show what a material difference a small change in the form of a model may make in the quantity of water which will flow over it under a given head.

The constants for the equation for these weirs are given in Table F.

II.—Comparison of Various Methods of Measuring the Depth of Water on the Crest of a Weir.

A.—General Remarks.

All the data presented under this heading have been obtained from experiments conducted under the direction of Professor Williams, in the Hydraulic Laboratory of Cornell University. These experiments, as far as the writer knows, comprise the most extensive set of this nature which has yet been made. Every detail of the investigation was watched with great care.

(1).—On Measuring Heads.

Each of the readings used for obtaining the head on the weir is the average of a series of readings taken during a period of from 15 to 30 min., during which time the head was kept as nearly constant as possible, and readings were taken at rates varying from two to six per minute.

One of these periods is called a run. The heads, in each of these runs, as measured by the standard tube-piezometer, have been plotted as abscissas, with the heads, as measured by the other instruments, as ordinates. The scale used is one gauge-scale unit, or one double centimeter, to the inch. The centers of gravity of the curves thus drawn were found first as a whole, then for each of the two halves of the curve, sometimes for the four fourths, and in a few cases for the eight eighths. Then, by passing lines analytically through some

or all of the points thus found, equations have been obtained which express the relation between the heads as accurately as that relation could be seen on the plottings.

These plottings, these equations, and their derivations, form a part of a thesis on "The Flow of Water Over Weirs" presented to Cornell University by the writer in 1903 for the M. C. E. degree. This matter is too extensive, however, to be reproduced in detail in this paper; but the heads as measured are given in Table A, and the results obtained are presented on Plates XCII and XCIII. These plates show how widely the obtained results may differ if the depth of water on the crest of a weir is measured in different ways, even though generally accepted by hydraulicians as methods which give correct results.

It is generally understood that, for computing the discharge of a weir, the head should not be measured less than 6 ft. up stream from the crest; therefore, the results obtained by measurements taken 6 ft. or more above the crest are shown independently in the upper part of Plate XCII. The abscissas represent the heads, as measured by the standard tube-piezometer, plotted originally on a scale of 1 in. to 0.1 ft., and the ordinates represent the differences between the standard-tube heads and those measured by some other method plotted originally on a scale of 1 in. to 0.01 ft.

The differences between the heads as measured by the standard-tube and those measured less than 6 ft. up stream from the crest of the weir are so great that, in order to show them within the limits of the plate, the vertical scale had to be reduced to the scale shown in the lower portion of the drawing.

(2).—On the Piezometer.

Before taking up in detail descriptions of the different measuring devices used in securing the data herewith presented, it may be well to state that, in general, the apertures of a piezometer are supposed to be made in a surface or in surfaces the elements of which are parallel to the direction of the line of flow of the water. The water flowing through these openings is conducted by a water-tight pipe to a vertical glass tube securely fastened to a framework. Next to the tube, and back of it, there is a carefully graduated scale, on which, with the aid of a rider, the elevation of the water can be read; this elevation is assumed to be the same as that of the surface of the water which covers the openings of the piezometer.

The capillary action of the water makes the surface of the water column in the glass tube assume the form of a meniscus with its convex side downward. As the lowest point of this surface is definite and easily seen, piezometer readings were taken by placing the index of the rider in the horizontal plane containing this lowest point. When the rider is thus placed, its zero is at the reading for that column of water.

(3).—On the Tape.

A "tape," as used in the hydraulic laboratory for measuring the depth of water on the crest of a weir, consists of a carefully graduated steel tape, with a plummet attached to it in such a way that the distance from the end of the tape to the point of the bob is constant. This tape, with the plummet attached, is hung over the end of a gradually, but not very sharply, rounded block, on top of which is a brass plate having a groove of proper width and depth to receive the tape. An index line, used to mark the reading on the tape, is made on the upper surface of this plate at right angles to the sides of the groove. When the point of the plummet is just touching the water, this index line is at the reading of the tape for that particular elevation of the water surface.

(4).—On the Point- or Hook-Gauge.

A word may be added here also to explain the method used when readings are taken with a point-gauge or a hook-gauge. Two blocks, some 5 ft. apart, and containing rectangular notches, are placed so that one is vertically above and symmetrically situated with respect to the other. These are used to keep the gauge in a vertical position, and a bolt-head or some other permanent mark, properly situated, receives the small bar or rest on the back of the rod, thus fixing the position of the index on the rod. The point, which is attached to the sliding portion of the rod, is moved vertically until it is in contact with the surface of the water. When thus placed, the index of the rod marks the gauge reading for the depth of water which is being observed.

(5).—On the Method of Getting Zeros.

The readings of these various instruments for various elevations of the water surface, are of value only when the height of the water surface, with respect to some particular and well-defined datum, can

be found from them. In weir work this datum is the horizontal plane containing the crest of the weir. The readings of these various instruments, when the water surface in the channel of approach coincides with this datum, are called the "zeros" of the various tapes, piezometers, or gauges.

For determining the zeros of the various measuring devices used, a hook-gauge was clamped to the crest of the weir on which heads were to be measured, care being taken to have the instrument attached in such a way that the movable upright bar was in a vertical position. The accuracy of this adjustment was tested by sighting in two directions at right angles with each other along the side of a plummet string held at arm's length. When this test showed the rod to be vertical, the point of the hook was, with great care, brought into the horizontal plane containing the crest of the weir by turning the screw on the instrument to which the vertical rod is clamped. When a small, carefully-tested pocket-level, placed with one end on the point of the hook and the other on the crest of the weir, showed the point to be on a level with the crest, the reading of the gauge was taken and recorded. The difference between this reading and any subsequent reading, taken with the point of the hook at the surface of the water, was the distance of the surface of the water below the crest of the weir. After making a careful comparison of the times indicated by the different watches used, and recording the results of this comparison, the observations were begun. During the observations the surface of the water in the channel of approach was kept but a short distance below the crest. Readings on the different measuring devices were taken as rapidly as they could be made with care, and these, with the time of each observation to the nearest second, were recorded. As it was practically impossible to keep the elevation of the water surface constant, several series of readings were taken in the manner just described, some with the surface of the water slowly rising, and others with the surface of the water slowly falling. At the close of each series of observations the times were again compared, and the reading of the hook-gauge, with the point of the hook in the horizontal plane containing the crest of the weir, was carefully checked.

By plotting these readings, using the times as abscissas and the readings as ordinates, curves were drawn showing the readings that any measuring device in use would give, if a reading had been taken

at any moment. Two times were selected, one near the commencement, the other near the close, of each run or series of observations, and the readings of the various instruments at the times selected were read from the curves. The distance of the water surface below the crest of the weir was the difference, as thus indicated, between the "zero" reading of the hook-gauge and the hook-gauge reading at the time selected. A correction equal to this difference, properly applied to the simultaneous readings of the other instruments, gave their respective zeros. The differences between the means of the zeros thus found and readings taken during the subsequent experiments were the heads required.

(6).—On Expressions Used.

Oftentimes, in this paper, by the reading of a tape, a gauge, or a piezometer, is meant the head of water on the weir as measured with the instrument named, and by the head of water on the weir is meant the vertical distance, in feet, between the horizontal plane containing the crest of the weir and the plane surface of the water in the channel of approach.

The different piezometers, tapes, and gauges considered have been called by names that tell, first, approximately how far up stream the head was measured, and, secondly, what the measuring instrument was.

B.—Measurements of Heads at the Standard Weir.

(Height 11.25 Ft.)

(1).—With the Standard Tube-Piezometer.

The standard tube-piezometer consists of the following: Three $\frac{3}{4}$-in. pipes, each 4 ft. long, and perforated with four rows of $\frac{3}{16}$-in holes, each row consisting of 12 holes 1 in. apart, longitudinally, and 90° apart circumferentially, the perforated portion being near the down-stream end. These three pipes are as nearly horizontal as may be, and are parallel to the walls of the channel. Each pipe is supported by two legs or pipes attached to its ends, one by a 90° elbow, the other by a T, the legs themselves being fastened to a base of two transverse and three longitudinal pipes resting on the bottom of the canal. The down-stream legs extend vertically to a height of some 4 or 5 ft. above the walls of the canal, and are left open at the top to provide a means of escape for any air which may be entrapped in the tubes below. (See Fig. 6.)

The pipes just mentioned are joined in such a way that water can enter them only through the perforations. By another $\frac{3}{4}$-in. pipe, attached to the base, the water entering the perforations is carried through the bulkhead, as shown in Fig. 6, and down stream for more than 100 ft. Here the pipe extends northward through the bottom of the canal wall into the gauge-house, where it is attached by a short piece of rubber hose to the standard tube (glass) 1 in. in diameter. The surfaces of the column of water in the tube and of the water in the chamber above the weir, are supposed to be in the same horizontal plane.

The south branch and the middle branch of this piezometer are shown clearly in Fig. 6. The former is 23 in. from the canal wall, the latter is 6 ft. farther north, and the branch on the north side is 22 in. from the north wall. The distance from the crest of the weir to the nearest perforation in the south branch of the piezometer is 25.67 ft.; to that in the north branch, 25.63 ft. The lengths of the perforated portions of the three horizontal pipes, beginning with the pipe on the south side, are 1.01, 0.92, and 0.92 ft., respectively; thus the average distance of the centers of the perforated portions of the pipes above the crest of the weir is 26.12 ft. The north branch is 6 ft. 2 in. above the bottom of the canal, or 5 ft. 1 in. below the horizontal plane containing the crest of the weir; the corresponding measurements for the south branch are 6 ft. 3 in. and 5 ft. 0 in., respectively.

The heads, as measured by this standard tube-piezometer, are used as a standard with which the heads measured by the other devices are compared. (See Plates XCII and XCIII.)

(2).—With the 6-Ft. Longitudinal-Piezometer.

The 6-ft. longitudinal-piezometer consists of the following: A $\frac{3}{4}$-in. horizontal pipe perforated with four rows of holes 90° apart, there being thirteen $\frac{5}{32}$-in. holes in each row, with a longitudinal distance of 1 in. between their centers. Lines joining the diametrically opposite rows of holes make angles of about 45° with the vertical. The center line of this pipe is approximately $\frac{1}{2}$ in. from the south wall of the canal, and 3.8 in. below the horizontal plane containing the crest of the weir. The centers of the lines of holes in the pipe are 5 ft. $10\frac{1}{2}$ in. up stream from the crest. Eastward, the pipe extends 25 in. from the hole farthest east, and at this point the end of the pipe is closed with a

cap. Westward, the pipe extends through the bulkhead to the gauge on the bank of the canal below the weir, where the readings of this device are taken.

The pipe of the 11-ft. longitudinal-piezometer, which replaced the one just described and is similar to it, is the horizontal pipe shown in Fig. 6 attached to the canal wall. This pipe extends up stream from the crest of the weir, but is slightly below the level of the crest.

As shown on Plate XCII, the difference between the heads measured by the 6-ft. longitudinal-piezometer and those measured by the standard is almost constant, and is equal to 0.0032 ft., the standard tube-piezometer giving the smaller heads.

(3).—With the 6-Ft. Wall-Piezometer.

The 6-ft. wall-piezometer consists of a vertical $\frac{3}{4}$-in. pipe fixed or cemented into the canal wall in such a way that its perforated portion, containing $\frac{3}{16}$-in. holes, 6 in. apart, is flush with the plane side of the channel. The center of this pipe is 6.01 ft. up stream from the crest of the weir, and its uppermost hole is $28\frac{1}{4}$ in. vertically above the crest. At the top of the pipe, $37\frac{7}{8}$ in. above the crest of the weir (Fig. 5), a $\frac{3}{8}$-in. pipe-vent leads into the canal and thence vertically upward 1 ft. or more. At the bottom of the perforated pipe, which is about 12 in. below the crest of the weir, a connection projects into the channel and is attached to a pipe which extends westward through the bulkhead to the gauge. This piezometer gives slightly higher readings at all points than does the standard tube, and the difference between these readings is a uniformly increasing quantity from the lowest to the highest head measured, as shown on Plate XCII.

(4).—With the 6-Ft. Tape.

This tape was 2 ft. from the south wall of the canal and 6 ft. up stream from the crest of the standard weir.

For heads of less than 0.66 ft., the readings of the tape exceed those of the standard tube-piezometer, and for heads greater than this, the reverse is the case. (See Plate XCII.)

In the Cornell Hydraulic Laboratory Records* it is stated: "Notice that the standard tape [meaning what is here called the 6-ft. tape] is below the beginning of surface slope." This is the only indication on the laboratory records that the readings of this tape may

* Book 50, June 6th, 1901.

not be strictly relied on. If the measurements of this tape are affected by surface curvature, certainly all other measurements taken at the same distance up stream from the crest of the weir will be affected in a similar way. It is interesting to note, however, that, for all heads, both the 6-ft. longitudinal-piezometer and the 6-ft. wall-piezometer give readings greater than those measured by the standard tube-piezometer.

(5).—With the 10-Ft. Tape.

The 10-ft. tape was used in the center of the channel of approach 10.23 ft. up stream from the crest of the weir.

It was found necessary to use two right lines to show the relation existing between the heads as measured by this tape and the same heads as measured by the standard-tube piezometer. This relation is shown by a curve on Plate XCII.

(6).—With the 11-Ft. Wall-Piezometer.

The 11-ft. wall-piezometer consists of a ¼-in. opening in the canal wall, which leads into a vertical pipe extending upward inside a timber of the canal wall to the atmosphere, and downward a short distance below the opening; then it projects into the canal and is connected to a pipe which runs west along the south side of the channel and through the bulkhead to the gauge. The center of the opening is 10.70 ft. up stream from the crest of the weir and 0.3 ft. vertically below it.

One line, as shown on Plate XCII, represents the curve resulting from plotting the readings of this piezometer. It appears that for low heads the readings of the 11-ft. wall-piezometer are lower than those of the standard tube. This curve, however, would fit the points a little more accurately, as they are plotted, if, from its point of intersection with the standard line, it were drawn toward the origin. The difference, then, of the readings of this piezometer and those of the standard are zero for low heads, but they increase gradually until, for a head of 3 ft. by the standard-tube, the 11-ft. wall-piezometer gives a reading of 3.0398 ft. This difference, as seen on Plate XCII, makes a change of about 2% in the computed discharge of the weir.

(7).—With the 2-Ft. Wall-Piezometer.

The perforations of the 2-ft. wall-piezometer, made to receive the water, are in a vertical ¾-in. pipe, buried or cemented in the wall of

the canal in such a way that the portion containing the perforations forms a part of the plane side of the channel. The top of this pipe, which is $37\frac{7}{8}$ in. vertically above the horizontal plane containing the crest of the weir, has attached to it a $\frac{3}{8}$-in. pipe-vent leading into the canal and then vertically upward a distance of about 1 ft., as shown in Fig. 5. At the bottom of the perforated pipe, some 12 in. below the horizontal plane containing the crest of the weir, a connection leads into the channel and thence westward, close to the canal wall, through the bulkhead to the gauge on the bank of the canal.

The horizontal distance from the crest of the weir to the vertical line containing the centers of these perforations is $24\frac{1}{2}$ in. The center of the lowest hole is $5\frac{1}{8}$ in. below the horizontal plane containing the crest. From this point vertically upward, there are twenty $\frac{3}{16}$-in. holes 2 in. apart. The curve which results from plotting the heads as indicated by this piezometer is shown on Plate XCII. As only part of the curve could appear on the plate drawn to the large vertical scale used in the upper part of the diagram, the whole curve is drawn to a smaller scale in the lower portion.

(8).—With the Crest-Piezometer.

This piezometer consisted of a $\frac{1}{2}$-in. brass pipe, about 1 ft. long, set vertically in an upright plank which was buried in the concrete in such a way that the plank and the perforated portion of the pipe formed a part of the plane side of the canal. The centers of the perforations ($\frac{1}{8}$ in. in diameter and 1 in. apart) were vertically above the crest of the weir at its south end (Fig. 5). The lower end of this tube was attached to a pipe which led to the top of the bank of the lower canal where the gauge was placed.

The curve determined by the readings of this piezometer is shown on Plate XCII in the lower diagram, which is drawn on the smaller vertical scale. The great difference between the readings of this piezometer and those of the point-gauge at the crest is one of the most surprising and interesting features of this comparison.

(9).—With the Point-Gauge at the Crest (Bent).

The operation of this gauge is much the same as that of the Boston level rod when the line of sight is below the horizontal plane containing the bench-mark. The target, however, is replaced by a $\frac{1}{4}$-in., straight, round, pointed, bar, extending about 6 in. below the end of

the sliding portion of the rod. Instead, too, of having the bottom of the stationary part of the rod rest on the reference point or bench-mark, a small brass bracket is fastened to the back of this portion of the rod and is used to support it. The two ends of the rod are placed in the rectangular notches already mentioned, and thus the point is kept in the same vertical line when it is moved in taking a measurement. (See page 1575.)

The readings which determine this particular curve (Plate XCII, lower portion) were taken, supposedly, in the vertical plane containing the crest of the weir, but the statement is made* that when the point was at the crest level it was $\frac{7}{16}$ in. down stream from this plane. It is for this reason that the curve is marked "bent."

(10).—With the Point-Gauge at the Crest.

(After the point was straightened.)

The readings taken with this gauge, after the point was straightened so that it moved in the vertical plane of the crest of the weir, have been used to determine another curve, shown on the lower portion of Plate XCII. The description of this gauge is given on pages 1575 and 1581.

C.—Measurements of Heads at the Standard Weir (Height 6.65 Ft.).

(1).—With the 6-Ft. Francis Piezometer.

This device for measuring the depth of water on the crest of the weir consists of a $\frac{1}{4}$-in. circular orifice in a 6 by 12-in. brass plate; the center of the opening is 6 ft. $0\frac{1}{8}$ in. up stream from the crest of the weir, $4\frac{7}{8}$ in. below the upper edge of the plate, and $2\frac{1}{4}$ in. below the horizontal plane containing the crest of the weir. This orifice leads into a pipe which extends through a timber of the canal wall and is attached to the gauge on which the "Francis" readings were taken.

This instrument, like all the others from which readings were taken at this weir (the curves being shown on Plate XCIII), gives readings or heads smaller than the standard-tube piezometer with which it is compared. This, however, is to be expected, even if the readings are taken simultaneously, because the standard-tube measurements were taken at the weir 11.25 ft. high and the others at the weir having a height of 6.65 ft. The vertical distance between these curves, however,

* Book 50, Cornell Hydraulic Laboratory Records, May 24th, 1901.

is the same as if the comparison had been made with the heads of any other of the measuring devices.

(2).—With the 6-Ft. Bottom-Piezometer.

The orifice of this measuring device is a $\frac{1}{4}$-in. circular opening in a $\frac{3}{4}$-in. cap which is flush with the face of an 8 by 10-in. timber forming a part of the side-wall of the canal. The opening is 1 ft. above the bottom of the channel of approach and 6 ft. up stream from the crest of the weir. The pipe to which the cap is attached extends through the canal wall, where it is connected to the gauge.

The curve resulting from plotting the readings of this piezometer is shown on Plate XCIII.

(3).—With the 6-Ft. Float-Piezometer.

This piezometer consists of a plank, a $\frac{3}{4}$-in. pipe extending half way across the bottom of the canal, and a gauge on the outside of the canal. The 2 by 12-in. plank, 18 ft. long, and dressed on the north side, is on edge in the bottom of the canal with one end against the bulkhead; the other end is beveled at an angle of about 30° with the center line of the canal, for the purpose of directing away from the piezometer opening all water having a disturbed direction of flow. In the dressed face, which occupies the center of the canal, is placed a $\frac{3}{4}$-in. brass plug which contains a $\frac{1}{4}$-in. circular orifice leading into the $\frac{3}{4}$-in. pipe just mentioned. This pipe extends across the channel, through an 8 by 10-in. timber of the south wall, and is attached to the gauge just outside of the canal.

The center of the circular orifice which receives the water is 3 in. above the bottom of the canal and 6.00 ft. up stream from the crest of the weir.

The curve determined by plotting the readings of this piezometer is shown on Plate XCIII.

(4).—With the 6-Ft. Point-Gauge.

This instrument is described on pages 1575 and 1581. Readings with it, which determine the curve shown on Plate XCIII, were taken 6.00 ft. up stream. As this curve is determined by only sixteen points, the results it indicates have less weight than those given by curves determined by many more.

(5).—With the 10-Ft. Tape.

Readings by this tape were taken 10 ft. $4\frac{5}{8}$ in. up stream. Its curve is shown on Plate XCIII.

(6).—With the 13-Ft. Three-Tube-Piezometer.

This piezometer is constructed in the following manner: Three $\frac{3}{4}$-in. pipes (each $41\frac{1}{2}$ in. above the bottom of the canal, and each perforated for 1 ft. of its length) are attached by 90° elbows to six legs, one at each end of each pipe; these legs are connected by T's to two transverse and three longitudinal pipes which form a base on the bottom of the canal. Through all these pipes the water circulates freely and conducts the pressure into a $\frac{3}{4}$-in. pipe, more than 100 ft. long, on the bottom of the channel, to an opening near the bottom of the canal wall, through which the pipe extends to the "lower tube" (in the gauge-house), on which the readings of this instrument were taken.

The three pipes containing the perforations are parallel to the sides and bottom of the canal. In each pipe there are four rows of $\frac{3}{16}$-in. circular holes. These rows are 90° apart, and the holes in the rows are 1 in. apart. The perforations farthest up stream are $31\frac{1}{2}$ in. down stream from the up-stream legs previously mentioned, and the perforations continue down stream to within $6\frac{1}{2}$ in. of the down-stream legs.

The curve which the readings of this piezometer determine is shown on Plate XCIII.

(7).—With the 15-Ft. Tape.

Heads were measured with this tape 14.82 ft. up stream. The curve determined by plotting these heads is shown on Plate XCIII.

(8).—With the 16-Ft. One-Tube-Piezometer.

The 16-ft. one-tube-piezometer had only one perforated pipe; the 13-ft. three-tube-piezometer had three. The former instrument was replaced by the latter,* and the readings of both these piezometers were taken on the "lower tube" in the gauge-house.

This single perforated tube was 42 in. above the bottom of the canal and parallel to the direction of the flow, the center of the line of perforations being 15 ft. $8\frac{3}{4}$ in. up stream and 8 ft. $7\frac{1}{2}$ in. from the south side of the canal.

* Cornell Hydraulic Laboratory Records, October 18th, 1901.

The results obtained by measuring the heads with this piezometer are shown by the curve for this instrument on Plate XCIII.

(9).—With the Point-Gauge at the Crest.

The point-gauge has been described on pages 1575 and 1581. The difference between the readings of this instrument and those of the "standard" are so great that they cannot be shown on Plate XCIII, therefore the equations of the curve are given instead of the curve itself.

Let y = the readings of the point-gauge.

and x = the reading of the "standard," all in double centimeters.

For values of x between 14 double centimeters and 39.1 double centimeters,

$$y = 0.8427\ x + 0.125.$$

For values of x between 39.1 double centimeters and 41.5 double centimeters,

$$y = 0.8016\ x + 1.734.$$

(10).—With the Hook-Gauge in the Bazin Pit.

With the intention of measuring the heads on the lower standard weir (height 6.65 ft.) exactly as Bazin measured those on his standard weir, and thus justifying the use of Bazin's formula for computing the discharges over this weir, the "Bazin pit" was constructed in 1903.

Bazin's standard weir was 1.135 m. high, and he measured the heads on this weir in a chamber by the side of the canal into which the water entered through a 4-in. circular opening, the end of which was flush with the canal wall. The center of this opening was 5 m. up stream from the vertical plane containing the crest of the weir, thus making the ratio of the distance up stream, where heads were measured, to the height of the weir, 5 ÷ 1.135, or 4.42.

The height of the Cornell weir is 6.65 ft. and the distance up stream to the center of the 4-in. opening (3⅞ in. above the bottom of the canal) is 29.88 ft., making the ratio above mentioned 29.88 ÷ 6.65, or 4.49, a value almost exactly the same as that given by the conditions at Bazin's weir.

The Bazin pit, 5 ft. long, 3 ft. 4 in. wide, and 10 ft. 8 in. deep, has its length at right angles to the direction of the canal. The distance between the canal and the pit is 3 ft. 6 in. The sloping roof over this pit is shown at the left of Fig. 3.

The height of the water in the Bazin pit was measured with a hook-gauge which was firmly fastened to the timbering on the west side of the pit.

The relation between the heads measured in the Bazin pit and the same heads measured with the 15-ft. tape has been deduced from the readings herewith presented, these readings having been taken simultaneously. (See Table B.*)

Letting y = heads by the 15-ft. tape, in feet;

and x = heads by Bazin pit, in double centimeters;

the equation,

$$y = 0.06535\ x + 0.0029,$$

expresses the relation between them for heads up to 4 ft. From the relation thus expressed, the curve for the Bazin pit on Plate XCIII has been drawn.

III.—Hydraulic Laboratory of Cornell University.

A.—Description.

At the north boundary line of the campus of Cornell University, and on the south bank of the magnificent Fall Creek Gorge, is located Cornell's famous Hydraulic Laboratory. Fig. 1 shows the lower standard weir (height 6.65 ft.), a part of Fall Creek Gorge, the falls, the dam, the laboratory building, Beebe Lake, and the west end of the canal, as they appear during the high-water season. Fig. 2 is a clearer view of the laboratory building, the gorge, and the dam. Fig. 3 shows the west or lower end of the canal. The standard weir (height 11.25 ft.) at the east or upper end of the canal, Beebe Lake, and a portion of the forest on the campus of Cornell University are shown in Fig. 4. The canal is 10 ft. deep, 16 ft. wide, and 350 ft. long between the two standard weirs; its walls are of smooth concrete, and 18 in. thick.

The upper weir chamber, at the east end of the canal, is 59 ft. long, 17.7 ft. deep, and 16 ft. wide. It contains a baffle, 46 ft. above the weir. There are six sluice-gates at the head or east end of the canal, and the 10-ft. and 16-ft. tapes are located there. The position of the baffle below this weir can be seen in Fig. 4. The six sluice-gates are operated with rack and pinion by iron levers about 6 ft. long.

As detailed drawings and descriptions of the Hydraulic Laboratory

* With other Tables, filed in the Library of the Society.

of Cornell University have appeared in several publications,* no additional matter need be given here. The various gauges, tapes, piezometers, and other devices used for measuring heads have already been described.

B.—Method Used for Measuring Water.

In the Cornell Laboratory there was no equipment by which the discharge could be measured volumetrically. The quantity of water which flowed over the standard weirs for known heads was compiled by using the weir formulas of Francis, Fteley and Stearns, and Bazin.

Experiments were made by running the same quantity of water over the two weirs in succession, measuring the heads on both, and from these heads, by use of the three weir formulas named, the discharge was computed.

For computing the quantities of discharge in this paper, Bazin's formula has been used, or, what is equivalent to the use of this formula, the curve previously mentioned (page 1556), which was constructed for the standard weir of height 6.65 ft.

The Bazin pit (page 1585) was put into actual use for the first time during the afternoon of June 22d, 1903. All heads read in this pit are used directly on the diagram for ascertaining the corresponding discharge.

By a long series of comparisons, the relation between the heads measured in the Bazin pit and those measured by some other method simultaneously, have been found, and this has been expressed in the form of equations. By the use of these equations, all heads read on either of the standard weirs have been reduced to equivalent Bazin pit readings before being used in the diagram.

It may be said, therefore, that the quantities of water herein given as being measured in the Cornell Hydraulic Laboratory have been determined by using a weir similar to Bazin's standard. The heads on this weir were measured just as Bazin measured them, and the quantities were computed from the heads thus read by using Bazin's formula (page 1556).

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* *Engineering News*, Vol. 41, March 2d, 1899. *Transactions*, Am. Soc. C. E., Vol. XLIV, p. 285. "Report on New York Water Supply," by John R. Freeman, M. Am. Soc. C. E., p. 129. "Accuracy of Stream Measurements," by E. C. Murphy, M. Am. Soc. C. E., for U. S. Geological Survey, p. 60. "Weir Experiments, Coefficients, and Formulas," by Robert E. Horton, M. Am. Soc. C. E., Water Supply Paper No. 150, U. S. Geological Survey, p. 86.

In all the Cornell experiments a correction has been applied for leakage. Leakage runs were made frequently in order to determine the amount of this correction. By using saw-dust to stop up the small openings around the gates in the lower end of the canal, the leakage was kept small.

C.—Method of Running Experiments on Models.

Some of the models on which experiments were performed were built over the upper standard weir (height 11.25 ft.) and others were built over the lower standard weir (height 6.65 ft.). When a model was built over one weir, the quantity of water used during the experiments was measured over the other. After opening the sluice-gates at the upper end of the canal a sufficient height to give approximately the head desired, and waiting from 10 to 30 min. for conditions to settle, readings on the various devices for measuring the head on the model and on the standard weir were begun, and these were continued for from 10 to 30 min. The means of the readings taken during a run were used to determine the head for that run or experiment. The readings for all the devices from which the mean readings were derived were taken during the same period of time.

The differences between these mean readings and the zeros of the instruments used were the head required (page 1575).

While the experiment or run was in progress, independent check readings were taken on all the measuring devices.

IV.—Hydraulic Laboratory of the University of Utah.

A.—Location.

The Hydraulic Laboratory of the University of Utah is on the small city reserve, in the eastern part of Salt Lake City, just north of the University campus. This enclosure contains the Thirteenth East Street Reservoir (a part of the city water-works system), the Hydraulic Laboratory of the University of Utah, and a small area surrounding them. Figs. 7, 8, and 9 are general views of the laboratory and the reservoir. Fig. 13 contains a general plan and two cross-sections of these structures. The authorities of Salt Lake City have very kindly permitted the University to construct the canals, pipe lines, measuring basin, and laboratory building on city property, and

allow the city water coming to this reservoir to be used in the laboratory.

B.—Source of Water Supply.

The water supply for the Thirteenth East Street Reservoir comes from Emigration, Parley's, and Big Cottonwood Canyons, which are in the Wasatch Mountains, south and east of Salt Lake City.

C.—Pipe Lines.

The water is carried to a settling tank and valve-house east of the reservoir in closed pipes and conduits. From this valve-house the two pipes leading directly west are shown in part on Fig. 13. One is an 18-in., vitrified pipe, the other a 12-in. cast-iron pipe. The 18-in. vitrified line leads into the reinforced concrete "intake" box of the laboratory, from which water is taken to the laboratory proper through an 18-in. machine-banded wood-stave pipe, 750 ft. long. The 18-in. vitrified line leading from the "intake" to the reservoir serves only as an overflow, as its upper end is some 4 ft. higher than the upper end of the pipe leading to the laboratory. This over-flow pipe has at its upper end a 90° bend into which, bell-end up, a length of vitrified pipe is fastened. This gives the outflow line a comparatively great carrying capacity for only a slight increase of head; thus it assists greatly in keeping constant both the heads and discharges in the laboratory. The valves regulating the quantity of water used in the laboratory are at or near the lower end of the supply pipe. As the fall from the intake box to the laboratory is about 70 ft., the hydrostatic pressure available in the laboratory from this source is about 30 lb. per sq. in. There is available for use in the laboratory, however, a supply of water from a 6-in. city main which will produce a hydrostatic pressure of about 160 lb. per sq. in. When the equipment for the building is put in place, a connection will be made with this line.

D.—Canals and Measuring Basin.

The canals and measuring basin in the laboratory are of concrete reinforced with steel rods. The walls are vertical on the inside and battered on the outside. The floors or bottoms of these structures are practically horizontal. It would be much easier to clean them if the bottoms had some slope.

(1).—Canal No. 1.—Baffle.

At the upper end of Canal No. 1 (shown at the right of Fig. 10) there is a receiving basin 8 ft. square having on three sides walls 10.28 ft. high. The water is discharged vertically from the wood-stave pipe into this basin through an 18-in. cast-iron bend, which is shown in the cross-section of the south end of the laboratory building.

From this basin the water flows through a baffle (marked on Fig. 13) into Canal No. 1. The bottom of this canal is 1 ft. higher than that of the intake basin. Its walls are 6.28 ft. high, and it is 2 m., or 6.56 ft., wide and 50 ft. long. This canal is seen at the right of Fig. 10.

This baffle is near the upper end of the canal, and is of timbers, 6 in. wide and 1½ in. deep, which fit into vertical grooves in the canal walls (Fig. 10). The individual timbers are 6 in. wide on the up-stream side, 3 in. wide on the down-stream side, and 6 in. thick horizontally. One of these timbers can be seen above the water in Fig. 10. The space between these timbers is 3 in. wide on the up-stream side, 6 in. wide on the down-stream side, and 6 in. across in a horizontal direction, the same as the timbers. These timbers are fairly well shown in Fig. 11, which is a view of the baffle in the upper end of the measuring basin. These three baffles are similarly constructed, and their locations are marked on Fig. 13. The theory on which these baffles are built is that both the "head" and the velocity of the water passing through these spaces, or rather "sudden enlargements," will be greatly decreased.

(2).—Canal No. 2.

From Canal No. 1, water can flow into Canal No. 2 in two ways—either over the weir in the lower end of the former channel or through the 12-in. by-pass valve just outside the canal near its lower end. From the bottom of Canal No. 1 to the bottom of Canal No. 2 there is a vertical drop of 5 ft. This canal, like the former, is 2 m., or 6.56 ft., wide and 50 ft. long. Its walls are 8.28 ft. high. The baffle is similar to that just described. The upper timber of the baffle, and the whole of this canal, with the weir and by-pass valve at its lower end, are shown clearly in Fig. 10.

(3).—Canal No. 3.

From Canal No. 2 water can flow into Canal No. 3 in the same two ways as those just described, namely, over the weir and through

the 12-in. by-pass valve (Fig. 10). The straight portion of this canal is 62 ft. long, the walls are 3 ft. high, and its width is also 6.56 ft. Its bottom is at the same elevation as that of the one above it. Instead of using a valve for a by-pass from this canal, a hole, semicircular at the top and 6 in. in diameter, with a width of 6 in. at the bottom, is cut through the wooden bulkhead at the bottom of the canal. A piece of 1-in. lumber covered with rubber packing or gasket serves to keep water from flowing through this opening.

(4).—The Measuring Basin.—Method of Determining Capacity.

The measuring basin in this laboratory is 150 ft. long, 16 ft. wide, and its walls are 10 ft. high. Therefore its nominal capacity is 24 000 cu. ft., or 180 000 gal. The west wall is shown just above the coping of the reservoir wall in Fig. 7. The inside of the basin can be seen in Fig. 8, also the bulkhead of 12 by 12-in. timbers at its lower end, with the stem of the 12-in. by-pass valve just above and to the right of them. The top of the baffle in the upper end of the basin is shown only slightly in Fig. 8. It is seen clearly, however, in the lower portion of Fig. 11. A good view of the west wall of the basin with its buttresses is shown also in Fig. 12. The wasteway at the lower end of the basin, with water flowing over it, is shown at the left of Fig. 7.

At the upper end of the basin there is a cast-iron waste-gate, 2 ft. wide and 2 ft. 6 in. long, which rotates on hinges at its upper edge. When closed, the plane of this gate makes an angle of 30° with the vertical; when open, it is practically horizontal. The gate is opened with a chain, one end of which is attached to the gate and the other to a round 2-in. rod operated with a lever and ratchet.

The water from this gate and that wasted by the diverting apparatus flows into the reservoir through the reinforced concrete channel shown in Figs. 7, 9, and 12.

By careful measurements, the areas of horizontal cross-sections of this basin, 1 ft. apart, have been ascertained. The lengths and widths of these sections were found by using two plumb-bobs. For example, to find the length of a particular section, the two plumb-bobs were hung near the ends of the section and in a plane parallel to the sides of the channel. The distance required is that between the two strings, plus the two distances of the strings from their respective walls. The distance between the strings was measured accurately and conveniently

with a steel tape, and that from the wall to the string, at any desired point, with a rule graduated to hundredths of a foot.

(5).—Diverting Device.

As shown in Fig. 12, the device for diverting the water into and over the edge of the measuring basin is a car, or sloping channel, on wheels. With the car in the position shown, the water is flowing into the measuring basin. If the car were pushed to the right until its vertical ends and those of the walls of the canal were in contact, the water would flow along the bottom of the car and be discharged outside of the wall of the measuring basin and into the concrete wasteway shown in the figure. The plan and cross-section of this portion of the laboratory (Fig. 13) also show how this device operates. The inside of this car, in horizontal projection, measures 8 ft. in the direction of the slope and 7 ft. at right angles to it, and the bottom has a slope of 1 ft. 9 in. The wheels run on iron rails. The channel or body is lined with galvanized iron. At the east end of the car (Fig. 12) there is a framework the vertical members of which are channel irons in which a wooden gate slides. The gate can be lowered suddenly with the trip shown in the figure. If the gate is lowered in this way, when a comparatively large stream of water is being wasted, the force of the water assists materially in pushing the car to the left so as to allow the water to flow into the measuring basin. For small streams, the sharp and turned-up cutting edge of the galvanized-iron lining of the bottom of the car, seen clearly in the figure, can be passed easily and quickly through the flowing stream without the aid of the water. The time at which the diversion is made can be observed accurately, and therefore the time of beginning and closing a run can be determined.

(6).—Weirs.

At the lower ends of the concrete canals there are weirs with sharp edges and without end contractions. These are of 4 by 4-in. timbers with 6 by $3\frac{1}{2}$ by $\frac{3}{8}$-in. angle irons on top, the 6-in. leg being vertical. The edge of this vertical leg is machined carefully and placed accurately in a horizontal position.

The crest of the weir in Canal No. 1 is 3.72 ft. above the bottom of the channel of approach; that is, its height is the same as that of

Bazin's standard weir. The height of the weir in Canal No. 2 is 6.65 ft., the same as that of the lower standard weir in the Hydraulic Laboratory of Cornell University; the height of Weir No. 3 is 1.64 ft. The nominal lengths of all these weirs is 2 m., or 6.56 ft.

Weir No. 1, for all the experiments made on it and contained herein, had its length cut down from 6.56 ft. to 1.77 ft., so as to get a higher head with the water available. One side of the channel of approach for this short weir was composed of a framework of 2-in. plank which extended 20 ft. up stream. Water stood at the same elevation on both sides of this partition. The bulkhead constructed in the vertical plane of the weir was made water-tight.

(7).—Pits for Stilling Water.

Above Weirs Nos. 1 and 2, pits have been built on each side of and touching the outside of the canal. These have been patterned after those used by Bazin.

Above each of these two weirs there are four pits, shown on Fig. 13; two are 6 ft., and two are 16 ft. 6 in., up stream from the crest. These pits have the same depth as the canal to which they are attached. The water is admitted to them through a 4-in. pipe having its ends cut off flush with the side of the channel. These pits have equal horizontal measurements of 1 ft. 6 in. inside.

E.—Measuring Heads.

Although the actual heads on these weirs could be measured most accurately, perhaps, in the stilling pits just described, they have not been measured in this way because, under usual conditions in practice, this cannot be done. As the reading of heads with a tape and plummet is a method which can be applied easily to almost any case, it has been adopted in the Hydraulic Laboratory of the University of Utah.

For measuring heads on Weirs Nos. 1 and 2, each tape is 15 ft. up stream from the weir crest. For Weir No. 3 the tape is 5 ft. up stream from the crest. The zero readings of these tapes were determined in the manner described on page 1575.

The depths of water in the measuring basin at the beginning and end of a run are measured by two tapes simultaneously, one near the south and the other near the north end of the measuring basin.

V.—Notation.

Q = Quantity of flow, in cubic feet per second per foot of length of weir;

Q_m = Quantity of flow, in cubic feet per second per foot of length of weir, as actually measured;

Q_c = Quantity of flow, in cubic feet per second per foot of length of weir, as computed by the trial formula, log. $Q_c = 1.5000 \log. h + 0.5000$;

Q_B = Quantity of flow, in cubic feet per second per foot of length of weir, as computed by the Bazin formula;

h = Head, in feet, on the weir, or the vertical distance between the plane containing the surface of the water in the channel of approach and the horizontal plane containing the crest of the weir;

Ht. or Height = Height, in feet, of the crest of the weir above the bottom of the channel of approach;

"15-Ft. Tape Head" means that the head on the weir was measured with a tape and plummet 15 ft. up stream from the crest of the weir;

K = the term $\left[1 + 0.55 \left(\frac{h}{p + h}\right)^2\right]$, in the Bazin formula:

$$Q_B = \frac{2}{3} \left(0.6075 + \frac{0.0148}{h}\right) \left[1 + 0.55 \left(\frac{h}{p + h}\right)^2\right] h \sqrt{2 g h}.$$

VI.—Comments and Acknowledgments.

Much of the information contained in this paper, as has, no doubt, been observed, is based on the results of investigations carried on in the Hydraulic Laboratory of Cornell University. These experiments were all performed under the close personal supervision of Professor Williams, to whom the writer is indebted for several corrections in the descriptions of apparatus used, and for many helpful suggestions during the whole period covered by the preparation of this paper. It was Professor Williams who pointed out the way that led to this study, and who, while the writer was a graduate student at Cornell University, drew the writer's attention to the fact that "the formula, $Q = m h^n$, is a perfectly logical one, and about the simplest that can be applied to the flow of water."*

* *Transactions,* Am. Soc. C. E., Vol. XLVII, p. 369.

The methods used in working up the data are largely original, therefore, the progress made has been slow. Were the work to be done again, it could be accomplished in a fraction of the time that has been spent on it.

To Dr. Schoder, at present Engineer in Charge of the Hydraulic Laboratory of Cornell University, to Mr. T. J. Rodhouse, scholar in Civil Engineering, to Mr. Albin H. Beyer, to Claude Berry, and Charles R. Wyckoff, Associate Members, Am. Soc. C. E., and to Mr. K. B. Turner, instructors and graduate students doing experimental work in hydraulics in Cornell University during the years 1902-04, the writer is indebted for assistance in performing the experiments, and in making computations on the original data.

For assistance in conducting the experiments in the Hydraulic Laboratory of the University of Utah and in making the final computations, the writer is indebted to Mr. Frank W. Becraft, and for the excellent work in drafting shown on the plates he is indebted to Mr. Hugh C. Lewis, University of Utah. The writer must also mention the fact that valuable suggestions and assistance have been received from Messrs. Thomas F. McDonald, A. Z. Richards, T. Ross Wilson, Jr., and Junius J. Hayes, all graduates of the State School of Mines, University of Utah, and former students in hydraulics in the classes conducted by the writer.

Finally, the writer should mention the excellent work of Mr. Clinton C. Cass, the Mechanician of the Hydraulic Laboratory of Cornell University, who constructed the models, also Messrs. Charles Forsberg, Master Mechanic, and John A. Carlson, Head Carpenter, University of Utah. Dr. J. H. Paul of the University of Utah reviewed the manuscript.

AMERICAN SOCIETY OF CIVIL ENGINEERS

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PAPERS AND DISCUSSIONS

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IRRIGATION AND RIVER CONTROL IN THE COLORADO RIVER DELTA.

Discussion.*

By H. T. Cory, M. Am. Soc. C. E.†

H. T. Cory, M. Am. Soc. C. E. (by letter).—The writer has been surprised and greatly interested at the reception of this paper by those connected with the several interests involved. Though especial effort was made to be fair and dispassionate in the presentation of the various features of the work and situation, yet so much bitterness has been engendered between many of the various agencies in the development of the region that it was felt impossible to write anything worth while and avoid causing, in many quarters, a feeling of unfairness. The discussions by Mr. Sellew and Mr. Chaffey contain all matters of that kind of which the writer has been able to learn, and Mr. Chaffey's discussion deals primarily with matters concerning which the writer at no time had any personal knowledge. The other discussions, numerous conversations, letters from officials of the Southern Pacific Company, of the United States Reclamation Service, of the Interior and State Departments of the National Government, of the California Railroad (Public Utilities) Commission, of the California Development Company and most of the Mutual Water Companies in Imperial Valley, of the Imperial Irrigation District, and from Mr. Rockwood and several of his associates in the project, have all expressed appreciation for the fairness of the presentation. In several cases minor changes in wording have been suggested, but it is a source of much pleasure that all these seemed to be not only fair but an improvement, and every one of these changes has been made. Mr. Cory

* Continued from August, 1913, *Proceedings*.

† Author's closure.

Mr. Cory. The writer must confess that he has often felt very pessimistic and impatient about the unreasonable attitude and stubbornness of a prejudiced man, and therefore such a result is most interesting and encouraging. Possibly, after all, misunderstanding is responsible for much of the failure to appreciate the work and real motives of others. At any rate, this is a striking illustration of men of affairs taking a common ground, or at least a tolerant appreciation of others' actions and opinions, when all the facts of a complex situation are systematically set forth in an apparently fair and comprehensive way, even with the handicap of strong feelings in the matter based on partial or misleading information. If such better understanding will result in less misapplied energy in completing the work thus started, the writer's efforts will be very well repaid.

The next most interesting things brought out by the discussions are the opinions as to the contents of the paper. Mr. Sellew regrets that the record of engineering operations was "partly obscured by a mass of legal and financial entanglements which properly have no place in a purely engineering article." Mr. Elwood Mead, on the other hand, finds that this same obscuring "mass of legal and financial entanglements" is the most valuable part of the paper, saying:

"The chief value of this paper, however, is not found in its description of the engineering methods used, but in the social and political conditions, attending irrigation development in the West, which it reveals. * * * as these are fundamental features of irrigation development, it is that portion of the paper which the writer proposes to discuss."

Mr. Buck confines his discussion largely to criticizing sharply Mr. Sellew's view. President Swain, in his annual address recently delivered before the Society, urges engineers to feel that their duty is to study and deal with financial, legal, and even social entanglements, and not those only of physics and applied mechanics. The views of various individuals in this regard are no doubt characteristic of their respective holders and the result of their life experiences.

Mr. Robson has added a more detailed study of the evaporation at the Salton Sea and shows that the figures given in the paper were somewhat too large, surprisingly small though they seemed. It might be well to point out that the coefficient, 0.6, derived by Mr. Robson for 6-ft. pans becomes, by Professor Bigelow's formula, 0.49 for 4-ft. pans and 0.4 for 2-ft. pans, in estimating the evaporation from large water surfaces from experimental small-pan data.

Mr. Knowles expresses the feeling, shared by many engineers as well as laymen, that reservoirs on the head-waters and along the tributaries of streams subject to disastrous floods offer the best means of flood control in theory, and ofttimes in practice. It is probable, as a

matter of fact, that Messrs. Knowles, Sellew, Grunsky, and the writer are not far apart in this matter, and that all agree that the extent to which such methods may be feasible differs with each stream. Mr. Knowles asks for data relative to this question, but it is believed that those presented by Mr. Sellew and the writer are all there are. Mr. Cory

Concerning these data, however, it is important to remember that neither Mr. Sellew nor the writer has any personal knowledge of the storage possibilities in the water-shed, and both agree that the available published facts are not sufficient to determine the feasibility of complete, or the extent of practicable, reservoir control of the Colorado River. Consequently, the conclusion reached by Mr. Sellew, as a result of his analysis, that there is but one available reservoir site—Browns Park with a capacity of 2 200 000 acre-ft.—on the entire Colorado River water-shed, is not only startling but quite unwarranted. Furthermore, the statement that "storage on the Gila is out of the question, as this stream carries more silt during its flowing season than the Colorado," is quite out of accord with the opinions of his superiors in the U. S. Reclamation Service, as the Roosevelt Dam has just been completed, creating a reservoir behind it having a capacity of 1 284 000 acre-ft. at a cost of $3 697 000, according to the first item of Table 23. This reservoir is on the Salt River, one of the main branches of the Gila, and has all the latter's essential characteristics.

As a matter of fact, many reservoirs will no doubt be constructed on the Colorado River water-shed, including probably the Kremmling site, in spite of the fact that at present it "is in the hands of interests foreign to irrigation or storage development," and these reservoirs will have considerable beneficial effect in reducing flood flows; it is immaterial whether or not the storage possibilities have been over-estimated, as this can only affect the extent of such an influence; but, as Mr. Grunsky says:

"Whatever this may be, it will not change the river problem, except as to its magnitude. * * * The same lack of channel capacity will be felt at high stages on the lower river as is felt to-day, and the same problem of keeping the delta channels of the river on the Gulf slope will confront the river engineers of the future as confronts those of to-day, except only that there will be somewhat less water and correspondingly less silt to be reckoned with."

This is especially true because below Yuma the river is practically a "joint track" for the Colorado and the Gila, which are very different types of streams, but each at times alone causes approximately equal maximum flood heights from Yuma to the Gulf. Of course, the floods on the Gila are flashy and those on the Colorado are long sustained, but that does not signify as much as might be thought, so far as river control is concerned. Fortunately, severe Gila and Colorado floods never occur simultaneously.

Mr. Cory. As to the quantity of water—the discharge of the Colorado at Yuma—the writer believes that the first half of Table 3 should be given, agreeing with Mr. Marshall that it is always best to set forth all available data, with explanations—as was done in this case—and let the reader decide what to use and what to discard. The recorded discharges prior to November, 1902, are by no means as reliable as those after that date, but that does not mean that they are worthless, though it does mean that they must be used with care and discretion. In this matter the comments of Mr. Grunsky on the reliability of the measurements taken since that time, especially at high stages, are very pertinent.

In any event, it seems clear that, beginning with 1905, the discharge of the river has been markedly greater than normal, and that long periods will occur when the discharge will be markedly less than normal—as is pointed out very well by Mr. Marshall. In the case he mentions the water is within 4½ ft. of the rail base on miles of the very expensive Lucin Cut-off crossing the Great Salt Lake, and the water is still rising. The relationship between yearly rainfall and run-off, even on very large water-sheds, and especially if few widely scattered points be taken, is by no means constant, as Mr. Marshall says, and as the writer and doubtless many others have learned from time to time to their discomfiture. With the existing data it is not safe to decide in more than a tentative way as to either maximum or minimum quantities. Mr. Sellew's maximum figures as regards river control are probably fairly close to the truth, but, with respect to the minimum for estimating safe irrigable acreage, caution must be used. Fortunately, it will be at least another decade before all the lands easily covered by canals in these regions can be brought under complete cultivation, and the dry cycle of years will probably be well under way, so that the safe limit of land which can be served by the natural flow of the river will be determined in time to avoid excessive development.

With respect to the rise of the river bed at Yuma, Mr. Sellew is correct in the opinion that much more information is necessary before definite relations can be established regarding it. The Southern Pacific Company, however, has kept gauge heights at Yuma since 1878, and these records show a steady rise of the river bed (taking averages), or a steady increase of the river discharge. The reader can judge which is more probably occurring. Also, the old maps on record in the British Museum, in archives at Madrid and Mexico City, and in the Bancroft Library in the University of California, have been carefully studied by Mr. Godfrey Sykes, of the Carnegie Institution, in connection with this very matter, and the final figures he has adopted (which will appear in a volume on the Colorado Desert by the Carnegie

Institution, now in press) check well with the "memory of a steamboat captain," Capt. Mellon, of Yuma, quoted by the writer in the paper. Mr. Cory.

Undoubtedly the difference in elevation at any two points on the river will change as the length of the river between these points is modified by meanderings of the stream; and, also, the two points, Laguna Weir and the conglomerate hills at Yuma, are the only ones on the lower river which may be regarded as definitely fixed—as was pointed out in the paper and again by Mr. Sellew. The latter, however, has mistaken effect for cause when he concludes that the increase of 4 ft. in difference of gauge height of the river at Yuma and Laguna Weir "is plainly caused by the meanders of the river" between these two points. This stretch of river had a normal length of nearly

DIAGRAMMATIC CROSS-SECTION OF LAGUNA WEIR

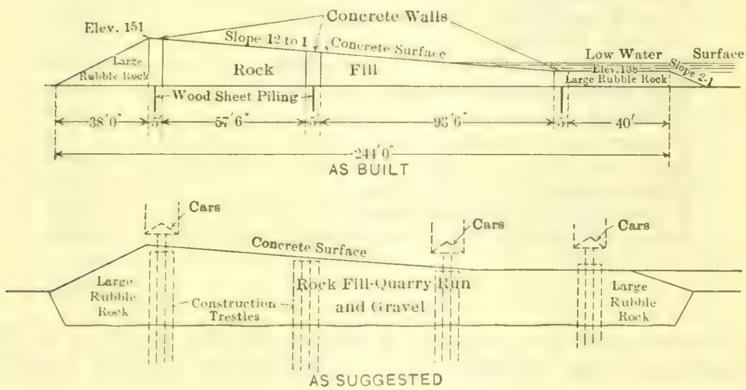

Fig. 46.

14 miles, from 1856 to 1909, and this had increased to 17 miles in 1912, because the stream had lowered at Yuma more than 3 ft. as shown by the diagram Fig. 3 (for reasons set forth in the paper), though no change is possible at Laguna Weir. The stream has reestablished its normal grade per mile by lengthening itself, and, as the bed at Yuma rises again, a corresponding shortening will follow.

It would seem that the comments in the paper as to the design and methods of construction of the Laguna Weir were not clear, either to Mr. Sellew or Mr. Grunsky. Fig. 46 shows diagrammatically a cross-section of the weir as built, and as the writer proposes. The resulting structures would not differ in function, concrete top, crest or foot walls, appearance when completed, or general design in the sense of cross-section above ground.

Mr. Cory. The difference is in the omission of the concrete cross-walls (which were very expensive in time and money) in the second design, and changes in the method of construction by driving the river sideways ahead of rock and gravel filling from trestles, and thus making it do all the excavation. The result would be a greater yardage of rock in the structure, but the total cost of it in place, including excavation and everything, would certainly not have been any more than the costs given for the material placed in closing the central section of the weir—undoubtedly it would be materially less on account of the much more favorable conditions and the larger quantities. The figures given by E. D. Vincent, M. Am. Soc. C. E., Resident Engineer on the work, and quoted in the paper, are, in round numbers, $1 per yard, made up of the following items*:

Labor, dumping cars	$0.020
Labor, general	0.020
Sundry supplies and implements	0.008
Railroad hauling	0.217
Depreciation, rolling stock and track	0.062
Excavation, rock-quarrying	0.468
Trestling	0.149
Proportion of storage of apron rock	0.014
Light and water	0.011
Depreciation, special derricks	0.001
Proportion of superintendence	0.032
Overhead charges, Yuma and Washington offices	0.038
	$1.040

Assuming the total quantity of rock in the weir proper to be even twice that in the structure as built, the amount required would be 750 000 cu. yd., or $750 000. Concrete facing and other items would hardly increase this sum to $900,000. As built, the weir proper cost $1 672 168.20. Mr. Clarke's comments on such methods of construction are very pertinent.

This suggested cross-section and method of construction is fundamentally different from that which Mr. Grunsky mentions as recommending in 1896 for a low dam in the Colorado in Iceberg Canyon—a dam to be constructed

> "of loose rock on a sand foundation by blanketing the bed of the river for a considerable distance up and down stream with broken rock, using large blocks for the down-stream portions of the work, allowing the water to bury these as deep as it would, and using finer material in the up-stream face, which would ultimately be made impervious or nearly so by the river silt."

* *Engineering News*, June 10th, 1909.

Mr. Cory.

Such cross-section design and method of construction is of course entirely independent of Mr. Grunsky's suggestion that the weir top should not have been uniformly high but have had a section, say 800 ft. long, a few feet lower than the rest, to hold the river in a definite position above the weir and to insure sweeping drift of whatsoever size over the structure.

Mr. Clarke's comments on "useless dredging" are most interesting—they differ materially from reports made by those who recommended, built, and are operating the dredge *Imperial* immediately below the Concrete Head-gate. It seems probable that this dredge has not entirely solved the silt problem in the Imperial canal system, as its advocates have enthusiastically proclaimed. Future results will be watched most carefully.

The writer regrets that he did not make clear that no levee failures were caused by the flood of December 7th, 1906, on that portion of the Yuma Project built under Mr. Sellew's direction, for, on taking charge of the Project, in October, 1906, Mr. Sellew at once ordered muck-ditching under all new levees. This had not been done before, and there were two failures from this cause opposite the Lower Heading on the Project levees, as stated in the paper and illustrated with a photograph, Mr. Sellew to the contrary notwithstanding. The writer remembers this most vividly, because his original design of levees included thorough muck-ditching, which was peremptorily ordered cut out as an avoidable expense, because, up to that time, none had been done in building the levees of the Yuma Project. After the disaster due to the flood of December 7th, 1906, careful examination of the damage to levees on both sides of the river was made and data were collected to show convincingly those not on the "firing line" that, with thorough muck-ditching, all completed levees on the river would have been effective, and the two failures from this cause on the Project levees were considered very significant.

The writer is inclined to agree with Mr. Sellew that the second break might not have occurred had the borrow-pits been on the river side, because of the peculiar facts of the short duration of that particular flood and the location of the breaks it caused. Nevertheless, the levee would have failed just the same in the several places. Also, muck-ditching would have prevented all trouble. When failure occurs, future construction designed with special reference to preventing that type of failure alone is most unwise, and it was felt that a failure similar to that which happened with the extension of the levees built later by Mr. Ockerson would be quite as disastrous as though caused by lack of muck-ditching or anything else. The design adopted was expected to prove safe from both these dangers, and, thus far, has done so entirely.

Mr. Cory. It is true that the recommendations of the first and second consulting boards as to levee construction and reconstruction were not followed—a careful reading of these recommendations and of the paper will, it is believed, convince the reader that this was wise. Especial attention is called, for example, to the recommendation on page 1509* to comply with which would have cost $12 000 per mile, though the total cost of the levees, exclusive of gravel blanketing, was considerably less.

As to the efficiency of the interrupted or checkerboard system of borrow-pits, Mr. Grunsky's observations coincide with the writer's, as set forth in the paper. There is no doubt that some—even though slight—additional security is obtained. The question in any case to be decided is whether it is great enough to justify the additional cost. The writer's opinion is that, as the materials grade more and more into those easily eroded, the available precautionary measures are, in their order of effectiveness: river-side borrow-pits with occasional short traverses; river-side continuous borrow-pits; river-side checkerboard borrow-pits; land-side borrow-pits; hydraulic-dredge-built levees, as described by Mr. Grunsky; and, lastly, blanketing with cementing gravel, concrete, etc.

The effectiveness and cost of checkerboard borrow-pits, and consequently whether or not to use them, must be determined for each individual case. With those soils and conditions of vegetation, grade, etc., where they will afford all the needed added security, considerable additional cost is justified; and, where this is not the case, little or no additional expenditures for them is wise. Similarly, as to the cost, with small levees, narrow berms, and easily handled soil—so that the haul is of maximum importance—the additional cost as a percentage will be greater, and *vice versa.* This difference, as set forth in the paper, was actually determined carefully by building adjoining sections of levee with continuous and with checkerboard borrow-pits, using half of one camp on each section and interchanging men and teams daily. Every effort was made to secure otherwise identical conditions, and it is believed with unusual success. The levee was uniformly 8 ft. high, 10 ft. wide on top, slopes, 3 to 1, berms 40 ft., borrow-pits with 50-ft. traverses each 400 ft. in one case, and 100 ft. alternately borrow-pits and undisturbed in the other, depth of pits in both cases, 2½ ft. at levee end and 4 ft. at far end. The material was the Colorado Delta silt described at length in the paper. The costs, excluding contractor's profits, were found to be 19 and 25¾ cents, respectively, per yard of embankment in place on completion; the settlement was very slight. This is in the ratio of 100 to 135.5. Mr. Sellew, with essentially similar work, done under normal instead of

* *Proceedings*, Am. Soc. C. E., November, 1912.

rush conditions, reports the costs as 11 and 13 cents, respectively—shop costs only—or in the ratio of 100 to 118. If the reader is interested as to the consistency of these two results, he can compute the average haul in the two classes of borrow-pits and check them up. Mr. Cory

The method of constructing levees by hydraulic dredges, as suggested by Mr. Grunsky, has been used to a considerable extent on the Sacramento River, although the material from the muck-ditch is there usually deposited on both the river and land sides of the trench, and the hydraulic fill made in the excavation and space between the two banks. The soil in that locality is such that it does not erode easily, and, more often than not, the levees are located on the river banks. With levees set well back and with the shallow, muddy Colorado, it is very doubtful whether such methods could be used successfully for levee building on that river. Furthermore, the amount of work done, especially during any one year, will probably be so small, and the deterioration and cost of handling a dredge on the lower river so great, that the total levee cost would probably be much higher than by the present methods.

Mr. Grunsky points out that the levees along the river have not yet been subjected to a conclusive test, and suggests two points: seepage under the levees with land-side borrow-pits, and reasons why the levees have not yet needed to be as high as were built. As to the former: miniature, pin-head, under-water volcanoes did appear, but their number and size did not seem to be large, when the effective head was greater, and after a time they stopped entirely. In not a single case did any of these become in any way menacing. Furthermore, last year the water-table rose above the ground surface behind the Reservation Levee of the Yuma Project with river-side borrow-pits, covering a considerable area, and seriously interfering with crops. The action is a rise of the underground water, and not seepage under levee structures.

The top grade line of the levees built under the writer's direction has proven to be higher than as yet required because of the abnormal overbank flow and cutting off of Nigger Bend in 1907 (as pointed out by Mr. Grunsky), and later by the Abejas Division, which did lower the river at Yuma, as shown by Fig. 3, and at all points below as far as the diversion, Mr. Sellew to the contrary notwithstanding. Indeed, it was this lowering at the Concrete Head-gate, which, with silting up in the Imperial intake, caused the building of the rock weir across the river at that point in 1910, as commented on by Mr. Clarke. Nevertheless, to have built lower levees would have been taking an unjustifiable risk. This is shown most strikingly by what happened with the levees near the Abejas Dam. In this case the levee grade was fixed by reference to the fresh high-water marks of the

Mr. Cory.

1909 flood which had its outlet down the Abejas, but after that closing was to be held in the old river channel. This latter did not scour down as was expected* and, had the levees held, they would have been overtopped in the vicinity of the dam by a 100 000-sec-ft. river that summer. Fig. 47† shows the situation there.

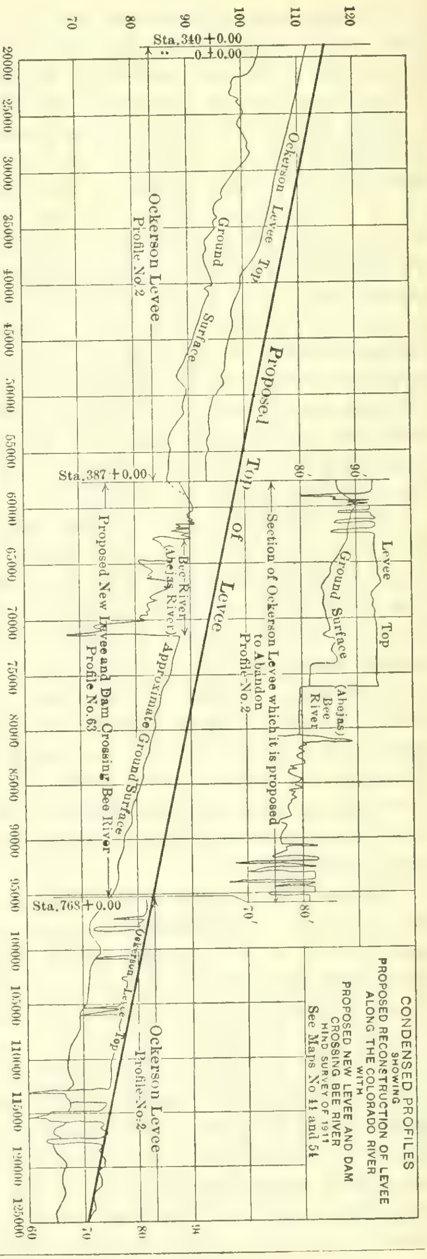

Fig. 47.

Mr. Grunsky believes the control of the Colorado between permanently fixed banks should not—at least for a long time—be projected beyond some agreed point near the Arizona boundary line, and in this he is joined by the Board of Review which reported on the failure of the Ockerson levees, the writer, and most of those who have been on the "firing line." The exceptions are Mr. Ockerson and Mr. Sellew. This is a matter of judgment, and all available data affecting the matter, for which a place could be made in a paper of this kind, have been given.

Mr. Follett confirms the writer's figures of land slope away from the river banks, and suggests the desirability of a secondary levee from the sand hills to the C. D. Co. levee, where it is a mile away from the river, with a gate structure where the main canal is crossed. This idea has been given careful

* See statement by Mr. Ockerson, *Engineering News*, Dec. 7th, 1911.

† Taken from House Document 504, 62d Congress, 2d Session.

consideration; the Board of Review just mentioned has reported that the money such a secondary levee of defense would cost could be more judiciously expended on the principal levees along the river. The writer agrees with the Board of Review in this. Mr. Cory.

The writer is surprised, on re-reading the paper on receipt of the discussions, to find so little had been said about bank protection work. This was partly the result of touching as lightly as possible on unsuccessful river control work done by others, partly because of a tacit understanding with other members of the Society as to the contents of the paper and their discussions thereof, and partly because, since holding the levee embankment on the north side of the Second Break in January, 1907, by gravel and rock revetment, as set forth in the paper and in Mr. Clarke's discussion, the proper way to do such work has seemed obvious. Messrs. Grunsky, Hind, Clarke, Herrmann, and the writer went over this matter together in June, 1907, and agreed as to the general procedure on the lower river—practically that concisely set forth by Mr. Clarke under the heading "Control of the River." Mr. Grunsky reported accordingly to the Secretary of the Interior at the time, and Mr. Sellew has now reached practically the same conclusions, except as to the important difference of reveting only at threatened points and so distributing the work over many years and letting the river do all dredging and placing gravel and rock well down to the limit of scour. In any event, the matter of funds will doubtless distribute the work over a long period, and the procedure recommended helps to arrange the "cutting of the garment according to the cloth."

With a railroad track on the levees, with large quantities of rock ready in near-by quarries and gravel pits in constant operation, and a very large railway organization which, at any time, on telegraphic notice, will send, for cost plus 10%, work trains, steam shovels, and a completely organized force, the methods of bank and levee production work here seem to the writer to be self-evident. All those who have had to deal with the lower Colorado, except Mr. Ockerson, agree as to the vital importance of a railroad track on these levees.

When thus equipped, and with the foregoing plan of river control and levee revetment, there is no reason for locating levees farther from the bank than needful to provide sufficient waterway for the greatest possible floods. Location farther back means on lower land and hence higher levees and greater difficulty to revet and hold when attacked by bend erosion. Such more distant levee location can at most mean a later date for completing the entire river revetment, and, outside of reasonable limits, this becomes a disadvantage rather than advantage.

Mr. Cory.

Consequently, the writer still feels that:

"Because of the various successful and unsuccessful work done in the region * * *, the Colorado River Delta now presents no unusual, unsolved engineering difficulties; its problems are chiefly matters of statecraft, in both river control and irrigation."

The writer joins with Professor Forbes in regretting that the exceedingly interesting geological sketch and historical review of the Colorado Desert, prepared as a part of this paper, by Professor Blake shortly before his death, could not be utilized in that way. Fortunately, it will appear elsewhere, and its reading is commended to those interested in this subject.

Mr. Chaffey's discussion is of especial interest, not only to the writer and those locally interested, but to many members of the Profession who never had a personal interest in the Lower Colorado. The corrections and criticisms it contains the writer can only admit to be fair; he regrets the inaccuracies in the paper which called them forth, and takes this opportunity to express his pleasure at their being presented. Since the paper was presented, the Supreme Court of California, in Thayer *vs.* California Development Co., finally held the system of mutual water companies and triparty contracts to be legal, and, in addition, commended such plan. This is the first decision handed down squarely on this point, though in other cases the District Federal Court and the State Supreme Court had by indirection practically decided just the opposite. It is, indeed, a sad state of affairs when it takes from 1906, when the first litigation began, until 1913, for investors and settlers to know definitely whether their operations and organizations are within the law. Mr. Mead is right in saying that at least three-fourths of the irrigation enterprises have been financial disasters because the laws were such that there was no adequate security for the money expended. So it is that, in spite of the legality of the plan as finally decided and its excellent basic business principles, it would doubtless have been better had the project been carried out under the Carey Act.

The writer takes pleasure in expressing appreciation of the standing of Mr. George M. Chaffey in irrigation work in the West. The Ontario Colony he founded in 1883 was selected ten years later as a model for the irrigation exhibit at the World's Exposition, and in his work at Mildura, Australia, he designed, had built in England, and installed, the first centrifugal pumps driven by triple-expansion engines, there being four pumps on the same shaft with a total capacity of 320 cu. ft. per sec. lifted 20 ft. He is at present, among other things, head of the magnificent water system irrigating 10 000 acres of citrus lands near Whittier, Cal., including the highest priced agricultural lands in California ($5 000 per acre). Furthermore, he is a man

of affairs and of large means which he acquired principally in irrigation enterprises and banking, and hence has the confidence of moneyed interests. Mr. Cory.

The comments of Mr. Chaffey and Mr. Marshall on soil examination and reports are pertinent and worthy of serious consideration. The effect of the soil reports on the Imperial region was most serious.

It is nearly a year since the paper was written, and in that time the maze of litigation over the Imperial Irrigation System has, if anything, become more complex. Arrangements have been made to supply water to additional lands by the Receivers of both the American and Mexican Companies for 50 cents per acre-foot, with a 10% free allowance for seepage and evaporation, and with no "water right" or water stock charge or requirement. Thus the later comers are getting water for their lands on better terms than the pioneers in the region, and the opportunity for bettering the financial status of both parent companies by the sale of valuable water rights—and so in the last analysis having the new-comers bear a proper share of the inevitable burden of readjustment, however that is to be accomplished—has been lost. This resulted from an unfortunate hostility between the two Receivers. Dr. Mead is certainly justified in his comments on laws governing irrigation projects.

The development of the country is going on more rapidly than ever, and land values have increased very markedly, due to the growing confidence of the outside public. The 1913 shipment of perishable products alone is 3 880 carloads, as follows:

Cantaloupes	3 499
Watermelons	338
Tomatoes	10
Other vegetables	26
Miscellaneous	7

A new high-line east side main is nearly completed which will water an additional 150 000 acres, and surveys have been completed for a Mexican Canal following closely the Paredones delta divide, crossing New River near Volcano Lake and thence northwesterly to the International Boundary Line near where it is crossed by the West Side Canal. These canals have no especially noteworthy engineering features, however.

No progress whatever seems to have been made in international negotiations looking toward joint governmental river control or conservation and division of the Colorado's waters between the two countries.

A very interesting and complete description of the Colorado River Siphon of the Yuma Project, by George Schobinger, Jun. Am. Soc. C. E.,* has recently been presented before the Society.

* Now Assoc. M. Am. Soc. C. E.

AMERICAN SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

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THE INFILTRATION OF GROUND-WATER INTO SEWERS.

Discussion.*

By John N. Brooks, Jun. Am. Soc. C. E.†

John N. Brooks, Jun. Am. Soc. C. E. (by letter).—In Table 14, which is a summary of the data presented in the discussion of this paper, the writer has included all the sewers mentioned, where sufficient data were given to permit of expressing the infiltration in gallons per mile of sewer. Four sewers in Table 1, for which the infiltration was stated only as a percentage of the total capacity of the sewer, have been omitted. Mr. Brooks.

The writer has examined the original sources of the data presented and has checked the figures in Table 14 with the original statements.

From the very complete data on the sewers of Ocean Grove, N. J., presented by Mr. Pugh, the writer has selected the quantities given in Tables 12 and 13 as representative results, and the figures in Table 14 for the Ocean Grove sewers are averages of the quantities in those tables.

In order to reduce Table 14 to a convenient size, certain abbreviations have been used, as noted at the bottom of that table.

In Columns 15, 16, and 17 the quantity of infiltration is expressed in three units.

In Column 15 it is given in gallons per 24 hours per foot of joint. This is the rational unit for pipe sewers, as suggested in the paper.

In Column 16 it is expressed in gallons per 24 hours per inch of diameter per mile of sewer. This unit is suggested by Mr. Gregory, as an improvement on that proposed by the writer for concrete and brick sewers. The writer accepts Mr. Gregory's unit as rational and convenient for both pipe and concrete or brick sewers. In examining the figures in Column 16 it should be borne in mind that though this

* Continued from May, 1913, *Proceedings*.

† Author's closure.

Mr. Brooks. unit gives a fair comparison between the infiltration in two sewers of similar type, vitrified pipe or concrete, it does not give a fair comparison between sewers of different types, because the entire length of a concrete sewer is porous, and, in a pipe sewer, infiltration is supposed to take place only at the joints.

In Table 5 Mr. Gregory computes the quantity of infiltration expressed in this unit for seven sewers, two of which (Items 11 and 17)

TABLE 14.—DATA ON THE INFILTRATION

Place.	Date of construction.	Date of test.	Type of section.	Material.	Diameter or dimensions, in inches.	Length, in miles.	Skill and care in laying.	Spacing and type of joints.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Boston, Mass.			Cr.	V. P.	8 to 36	137.00		
Mass. State					Various.	700.00		
Canton, Ohio						11.00		
Brockton, Mass.						16.00		
E. Orange, N. J						29.00		
E. Orange, N. J				V. P.	8 to 24	25.00		
Joint Trunk Sewer, N. J						150.00		
N. Brookfield, Mass					12	0.3		
Rogers Park, Ill.					6	1.7	Un.	Deep sockets.
Altoona, Pa.					27	1.2		
Altoona, Pa.					30	0.6		
Alliance, Ohio			Cr.	V. P.	15			
Clinton, Mass.								
Concord. Mass.								
Framingham, Mass								
Gardner, Mass.								
Madison, Wis.								
Malden, Mass.			Cr.	V. P.		38.00		
Marlboro, Mass.								
Natick. Mass.								
New Orleans, La.								
Reading, Pa.								
Westboro, Mass.		1899			15	0.37		
Stamford, Conn.	1888	1889	Cr.	V. P.	6 to 18	13.38		
Stamford, Conn.	1888	1892	Cr.	V. P.	6 to 18	13.38		
Canton, Ohio			Cr.	V. P.	20			
New Bedford, Mass.			Cr.	V. P.	12			
Fond du Lac, Wis.			Cr.	V. P.	24	1.33		
E. Orange, N. J			Cr.	V. P.	10 to 24			
Ocean Grove, N. J	1911	1912	Cr.	V. P.	4 to 12	3.25	Or.	3 ft. cement.
Ocean Grove, N. J	1911	1912	Cr.	V. P.	4 to 12	3.25	Or.	3 ft. cement.
Newark, N. J		1903				198.7		
E. Orange, N. J			R.	B.	24 by 36			
Westboro, Mass.				B.				
Altoona, Pa.			R.	B. & C.	33¼ by 44	0.95		
Peoria, Ill.				B. & V. P.				
New York City					8 to 24	5.00		
Columbus, Ohio	1906	1906	H. S.	C.	42 by 42	0.33		
Bronx Valley, N. Y.	1909	1912	Cr.	C. 1 : 2 : 4	44 to 72	9.04	Or.	None.

The following abbreviations have been used in this table: Cr. = Circular, Un. = Unusual, Or. = Ordinary, G. = Gravel, Q. = Quicksand, S. C. = Sandy clay,

have cross-sections other than circular. In these two cases he uses the average of the dimensions of the cross-section stated. If the resulting infiltration is to be compared with that found in sewers of circular cross-section, a fairer comparison will be made by using the diameter of a circle having a circumference equal to the perimeter of the sewer. Assuming the sewers (Items 11 and 17, Table 5) to have rectangular cross-sections of the dimensions given, and using the diame- Mr. Brooks.

OF GROUND-WATER INTO SEWERS.

Water-proofing, type and percentage of length.	Size and spacing of laterals.	Wet trench, percentage of total length.	Average head of ground-water, in feet.	Character of sub-grade.	INFILTRATION, IN GALLONS PER 24 HOURS.		
					Per foot of joint.	Per inch of diameter per mile of sewer	Per mile of sewer.
(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
					2.6	1 818	40 000
							80 000
							26 500
							25 000
			10	Q.			22 400
					0.8	540	8 650
				G. & Q.			25 000
					2.0	1 420	17 000
					0.3	207	1 240
					2.6	1 510	40 814
					5.0	2 890	86 592
					18.7	13 000	195 000
							32 500
		18	8				43 000
							31 180
							45 875
							48 000
		60					50 000
							59 540
							88 710
	30 ft. c. to c.						45 900
							5 172
		100				88 100	1 320 300
					6.0	4 110	49 340
					11.3	7 850	94 170
					5.0	3 500	70 000
					2.1	1 417	17 000
		100	5	C.	1.5	1 010	24 370
		100			4.7	2 540	43 250
	2 - 4 in. 50ft. c. to c.	100	3	S. C.	2.7	1 890	15 126
	2 - 4 in. 50ft. c. to c.	100	4	S. C.	7.9	5 480	43 764
							115 752
		100					570 000
							415 850
						5 390	264 000
							100 000
						81 400	1 300 000
						120	6 340
3 ply felt and pitch 4%	None.	80		G.		123	7 266

H. S. = Horse shoe, R. = Rectangular, B. = Brick, C. = Concrete, V. P. = Vitrified pipe, C. = Clay.

Mr. Brooks. ter of an equivalent circle in computing the quantity of infiltration, we have, for the Altoona sewer, 5 390 gal. per day per inch of diameter per mile of sewer, and 120 for the Columbus sewer, instead of 6 830 and 151, as computed by Mr. Gregory.

In Column 17 the infiltration is given in gallons per 24 hours per mile of sewer. This unit is retained as the most useful in cases where insufficient data are presented for the use of the preceding units.

Mr. Allen calls attention to the fact that in a collecting system a large proportion of the infiltration will come from laterals. An attempt has been made to recognize this factor by the addition of Column 11 in Table 14, stating the size and spacing of laterals.

In an impervious soil it may happen that a sewer, however carefully built, will be sufficiently porous to admit ground-water as fast as the soil can carry it. That is to say, the infiltration will be limited, not by the imperviousness of the sewer, but by the quantity of ground-water transmitted to it by the surrounding soil. Mr. Bradbury states that this is usually the case. In such a case the infiltration must be estimated as equal to the ground-water flow, data on which are presented by Messrs. Kuichling and Christian.

The data presented by Mr. Rankin, for the Joint Outlet Sewer, in Newark, and by Mr. Pugh, for the sewers of Ocean Grove, N. J., show that the quantity of infiltration follows closely the rainfall, indicating the direct dependence of the quantity of infiltration on the head of ground-water. The greatly increased infiltration into the Ocean Grove sewers in winter with a high ground-water level, as compared with that of the same sewers in summer, illustrates the same point.

The divergence of opinion among engineers as to the quantity of infiltration to be expected is well illustrated by a comparison of the comments of Mr. Christian and Mr. Kuichling on the infiltration reported by the writer for the Bronx Valley Sewer. Mr. Kuichling says:

"In comparison with the other observations cited herein, this rate of infiltration [0.8 gal. per day per sq. yd. of interior surface] is extremely low, and indicates either great water-tightness of the concrete, or an unusually dry subsoil at the time of measurement."

Mr. Christian says:

"From the speaker's experience with the construction of concrete sewers, he would regard this [infiltration] as rather high, unless there was some leakage at the joints, or where each day's work joins that previously laid; and he suggests that a careful inspection would find that to be true."

As noted in the paper, such an inspection was made, and no leakage was observed; and, further, the subsoil could not have been "unusually dry" because the sewer for its entire length lay beside, and, for a considerable portion of its length, directly beneath, a flowing stream. The low infiltration, therefore, is apparently due to tight concrete.

The data collected in Table 14 indicate that the quantity of infiltration is dependent on so many conditions, and may vary between such wide limits under apparently similar conditions, that the estimate of this flow in a sewer to be constructed, is a matter calling for the exercise of judgment enlightened by experience, rather than an attempt to apply a mathematical formula. Mr. Brooks.

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SHEARING STRENGTH OF CONSTRUCTION JOINTS IN STEMS OF REINFORCED CONCRETE T-BEAMS, AS SHOWN BY TESTS.

Discussion.*

By Alexis Saurbrey, Assoc. M. Am. Soc. C. E.

Alexis Saurbrey, Assoc. M. Am. Soc. C. E. (by letter).—In order to appreciate fully the importance of the tests under discussion, it seems necessary to take into account the earlier history of the principles involved. As a commercial proposition, the unit system referred to by the authors, was first used on a three-story building erected for the American Piano Company, at East Rochester, N. Y., in 1905, which was designed and constructed by the Ransome and Smith Company. This system, known as the "Ransome Unit System," has since been used on a number of one- and two-story buildings, and during the last three or four years, also on buildings from four to six stories high, notably those of the United Shoe Machinery Company, at Beverly, Mass. Mr. Saurbrey.

In view of the fact that all these buildings were designed along usual lines (except for the feature of the joint between slab and stem and other features connected with unit construction), and that they had been submitted to the test of actual service for several years, without developing any signs of weakness, there was really not room for much doubt as to the outcome of the tests described by the authors, that is, it was pretty well known that the joint would not prove detrimental. It was hoped, however, that the tests would show conclusively the limit at which the joint between slab and stem would separate, so that definite data might be available for future design of the stem and

* Continued from May, 1913, *Proceedings*.

Mr. Saurbrey. stirrups. While the test schedule was under preparation, the writer, then Chief Engineer of the Ransome Engineering Company, realized that Types *A* and *B* were equipped with an excess of stirrup reinforcement, and he therefore suggested Type *C*, with much lighter stirrups. To compensate for the resulting lower general strength of the beams, the arrangement of the tension rods was reversed, so that the heavier rods were placed on top, and trussed, as shown by the diagrams.

In addition to the experience gathered by the Ransome organization in regard to the effect of joints between slab and stem, it was known that the Hennebique engineers had used such joints, in monolithic construction, both in Europe and in this country. The writer is unable to state what the prevailing practice in Europe is at the present time, but, in this country, such joints are specifically prohibited by the building codes of most large cities. Why this should be, is hard to tell, as there seem to be no test data or other experience showing the joint to be dangerous in any way, except, of course, when the stirrups are inadequate, in which case the construction of T-beam sections would be dangerous without, as well as with, the joint. The writer has had occasion to discuss this question with a number of engineers and contractors, and opinions seemed to be fairly evenly balanced for and against the use of the joint.

Theoretically, it has been found possible to determine by calculation the proper number of stirrups for beams having a joint between slab and stem; and it is also possible to determine the maximum permissible spacing of the stirrups. These questions are dependent, for their solution, on the view taken of the action of the stirrups. The writer believes that the stirrups are stressed in tension, and not in shear, and that there is no shear in a properly designed, reinforced concrete beam after the stage of initial loading has been passed (when the steel is stressed above, say, 5 000 lb. per sq. in.), not even in the concrete; the views and arguments leading to this belief have been published elsewhere.* The tests under discussion seem to substantiate these views. (See, for instance, Fig. 1, Plate XXXIII.) The flaking of the surface of the beam is plainly discernible; the concrete of the stem has lost its cohesion to such extent that large pieces can be picked out with the fingers. In other words, the beam is nothing but a pile of loose pieces, held in place by the horizontal and vertical rods, and by the dove-tailing of the individual pieces. It is impossible to understand how concrete in this stage can transmit "shear stresses," which, it is known, involve tension stresses, and yet, these beams carried considerable additional load before they broke down entirely.

Under these circumstances, it seems futile to discuss the calculated intensity of the shear stresses. To the writer it seems that the steel, whether stirrups or main tension rods, carries the tension which un-

* "Reinforced Concrete Buildings," Ransome and Saurbrey, 1912, Chapter VII.

doubtedly occurs in both horizontal and vertical directions, and the loose filling of destroyed concrete carries the corresponding compressive stresses. When the destruction of the concrete reaches the end of the beam, the anchorage of the tension rods is finally destroyed, and the beam naturally fails. The writer mentions this with confidence, as he was present at most of these tests. He takes pleasure in acknowledging the unusual care exercised in placing the beams, measuring deflections, increasing the loads, in short, in everything pertaining to the testing. If any criticism could be offered, it would extend only to the neglect of moistening the beams from day to day, during the hardening period, and to the absence of control tests of compression specimens. In regard to the first point, the writer sees therein the cause of the observed fact that the beams 40 days old, and those 90 days old, had practically the same strength, for it seems to be well established that concrete will not increase much in strength after a certain period, unless it is kept in a moist condition. In regard to the second point, compression specimens would have been useful for comparison with other series of tests, and, therefore, would have enhanced the value of the tests as a whole. For the particular purpose of the tests under consideration, these objections are, of course, of no importance. Mr. Saurbrey.

The writer agrees with the authors' statement, namely, that "where adequate web reinforcement is provided with sufficient anchorage at the top, the slab need not be cast before the stems have set." That this is true for beams like those tested, is beyond doubt. That it would also be true for beams constructed along different lines may be inferred from the fact that both the flange and the reinforcement along the bottom of the beams, were purposely made unusually heavy, so that the stresses along the joint must of necessity have been abnormally high, whatever view one chooses to take of the action of the stirrups. David Gutman, M. Am. Soc. C. E., raises the point of the effect of a wider and thinner flange. It would probably be difficult to examine this point in the laboratory, where the width of the flange is determined by the construction of the testing machine. However, the anchorage of the stirrups in the slab is a factor of the greatest importance, and this detail is much more difficult in a thin slab than in one of generous dimensions. Otherwise, the writer does not see that the width of the flange enters into the problem.

In order to exhaust completely the possibilities of construction, many more tests will have to be made, and on account of the very real importance of the question, both in monolithic and unit methods of constructon, it is hoped that this will be done. It is in itself a considerable task to make and test 28 large-sized beams, as was done by the authors, and the beams tested were naturally constructed to conform, as closely as possible, to the problems encountered in the two buildings then under construction in Boston, and since com-

Mr. Saurbrey.

pleted. As far as the writer knows, no structural defects have developed in these two buildings, nor has the joint between slab and stem caused trouble in any of the buildings erected before these tests were made. It is to be hoped that the building authorities everywhere will recognize the importance of the information gathered by the authors, and revise their laws accordingly.

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FREMANTLE GRAVING DOCK: STEEL DAM CONSTRUCTION FOR NORTH WALL.

Discussion.*

By Joshua Fielden Ramsbotham, Assoc. M. Am. Soc. C. E.†

Mr. Ramsbotham.

Joshua Fielden Ramsbotham, Assoc. M. Am. Soc. C. E. (by letter).—Mr. Archer has referred to the penetration of the piles obtained on the shore side of the pumping station, and as it may be of interest the writer submits Fig. 7, showing a pile which failed; altogether, there were eight piles which went astray. It is only fair to state that the rock in the locality was as hard as bell-metal, and the behavior of the piles in no wise contributed to the abandonment of the work. The writer would again emphasize the advisability of not forcing the piles until soft ground has been found ahead of piles which have encountered a hard patch.

Mr. Archer is quite correct in his surmise that the hard wood (jarrah) permitted the omission of short foot-blocks.

For the information of the members the writer has forwarded, for the Library of the Society, two books‡ which give all details about the various timbers of Western Australia, and he ventures to suggest that that country has been singularly blessed by Providence in this respect.

No doubt Mr. Archer has observed that a larger factor of safety was allowed on the pumping station shores; this was because of the additional weight due to earth pressure and any surcharge from cranes, etc., and also on account of their length.

As regards the suggestions to the manufacturers, the writer begs to state that he gave freely any benefits of his experience at the time

* Continued from August, 1913, *Proceedings*.

† Author's closure.

‡ "Western Australian Timber Tests, 1906: The Physical Characteristics of the Hardwoods of Western Australia," by G. A. Julius, Second Edition, 1908; and "Notes *re* Timbers of Western Australia Suitable for Railways, Engineering Works, and Constructional Purposes Generally," Second Edition, 1908.

Mr. Ramsbotham. to Mr. U. V. Burke, Agent for the United States Steel Products Company, and also Consul for the United States of America, and Mr. Burke reciprocated with all particulars from the manufacturers; by this means the Engineering Profession is best served.

Mr. Archer is quite correct in assuming that there were no leaks in the joints; the skin was quite tight, and this tightness was obtained by the following method: Steel rods, 20 ft. long and $\frac{1}{4}$ in. in diameter, were procured, their lower ends were made an inverted **V** shape, and their upper ends a wedge shape with a small hole drilled through. A loop was made in one end of a strand of Italian gasket, the diameter not being increased. The inverted **V** end of a rod was inserted in this loop and the rod lowered in the space between the male and female piles by a fine string put through the eye. This was repeated by lowering another rod on a separate string with an additional length of gasket, until the entire length of joint was traversed. The gasket made a complete seal and, of course, the rods were removed.

In the first instance Oregon pine fillets were inserted when driving the pile, but there is no exaggeration in stating that they were completely eaten up by the teredo in one month.

Any small trickles can be cured instantly by throwing in a mixture of saw-dust, ashes, and horse manure.

The writer is glad to hear that Mr. Bellamy has used jarrah with success, and this opportunity is taken to supplement his remarks on this head.

Jarrah (*Eucalyptus marginata*) trees average 90 or 100 ft. in height and from 2 to 3 ft. in diameter at the base. The wood is very hard and dense, weighing when seasoned 60 lb. per cu. ft. It is used economically for railway sleepers, jetties, bridges, marine and engineering works of all kinds, building construction, flooring, wood blocking, boat building, fencing, furniture, etc.

Its strength is as follows: Shearing, 2 010 lb. per sq. in.; end compression, 9 050 lb. per sq. in.; cross-bending, 15 000 lb. per sq. in.; tension, 15 500 lb. per sq. in. Additional information regarding this wood may be found in the books previously quoted.

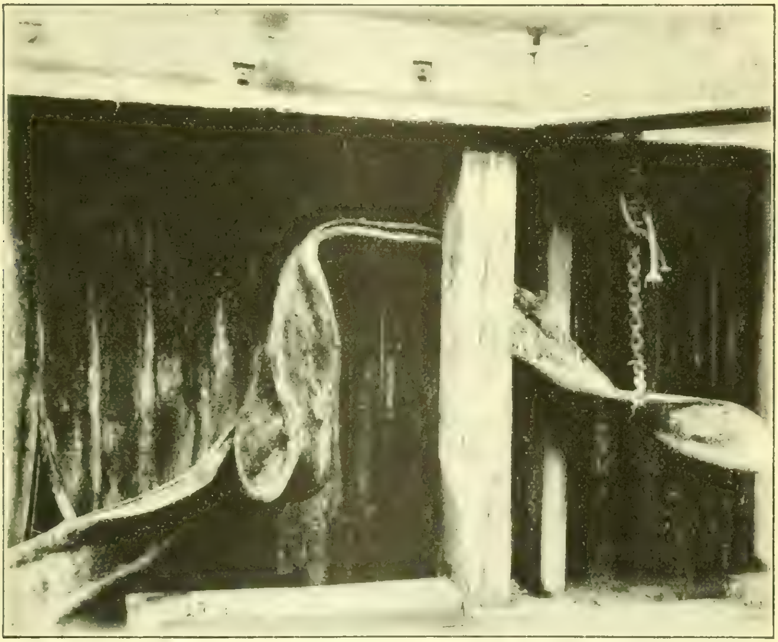

FIG. 7.—STEEL PILES DRIVEN ON WEST SIDE OF PUMPING STATION, NORTH WALL, FREMANTLE GRAVING DOCK.

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KINETIC EFFECTS OF CROWDS.

Discussion.*

BY C. J. TILDEN, M. AM. SOC. C. E.†

C. J. TILDEN, M. AM. SOC. C. E. (by letter).—Mr. Hilder and Mr. French raise a question which is somewhat outside the scope of the paper, namely, that of vibrations set up in a structure by the movements of its living load. This, of course, is one possible result of the kinetic effect of crowds, and if the swaying motion of the crowd is in unison with the vibration period of the structure, disaster may follow. This phase of the question, however, has to do more with the building than with the load on it, and, therefore, was intentionally omitted from the original investigation. Nevertheless, the writer is glad to have the point raised, and does not by any means underestimate its importance. Mr. Tilden.

The results reported by Mr. Quimby of his experiments with the swinging platform are not at all convincing. The existence of a backward-shoving force is clearly shown by the sudden backward swing of the platform, but to measure it by calling it equal to the force needed to hold the platform the same degree out of plumb, is surely a serious error. The immediate force-effect of a moving body on a freely swinging structure is very different from that of the same body, moving in the same manner, on a practically rigid structure. The writer still believes that the maximum possible backward push on a grand-stand, or similar structure, is much more likely to be 50%, or more, of the static weight than the 7% suggested by Mr. Quimby. Referring to the writer's computation, Mr. Quimby says: "The error is probably in the assumption that the horizontal movement is as rapid as the vertical one."

* Continued from May, 1913, *Proceedings*.

† Author's closure.

Mr. Tilden.

It is hard to see just where this "error" lies, as the two movements are made in precisely the same time, as a glance at Figs. 1 and 2, with their accompanying explanations, will show.

The absorption of a large part of these impulsive forces by "the inertia of the structure" is, of course, quite probable where the forces are isolated or result from the sudden movement of small and separated groups. It is when the movement is so general as to be practically unanimous that the resulting force on the entire structure may reach serious proportions. The experiment of interposing, between the man's feet and the scale platform, a mass nearly equal to the weight of the man, was tried by the writer, and the results reported in the last paragraph of page 328* and the lines A_x of Fig. 2.

Mr. French is quite right in saying that a heavy modern bridge, with solid floor, could hardly be seriously affected by the movements of a crowd of people. Unfortunately, however, such bridges are a very small part of all the bridges in use. It is not the "first-class permanent work" (to quote Mr. Coombs' expression) which needs attention along the lines suggested by the paper, but the much more common, more or less flimsy structures, often hastily built, and sometimes without proper supervision.

The writer believes that a general increase in loading requirements—possibly even to the extent of 50 or 60%—for structures likely to carry people would be wise and proper. Such a ruling would not materially affect first-class design, but would decidedly benefit the lighter classes of work. It is certainly better to be safe than to be economical, where human lives are concerned.

Emphasis is lent to this view by the reports of accidents of various kinds which frequently appear in the press. Two recent cases are commented on briefly:† The first of these was the accident at Lawrence, Mass., on June 30th, when a dozen boys, from 9 to 15 years of age, lost their lives through the failure of a narrow, wooden walk leading to a municipal bath-house. The Associated Press report said "the boys were jumping up and down as they shouted to the keeper to open up." The second instance was that of the second floor piazza of a tenement house at Brookline, Mass., which collapsed under the weight (plus kinetic effect?) of fourteen children, three of whom were badly injured.

The recent failure of the floor of an amusement pier at Long Beach, Cal., resulting in the loss of 35 or 40 lives, was fully reported in the daily and engineering press. It is simply another instance in which it is not hard to imagine the kinetic effect, or impact, of the densely packed crowd as being at least a contributory cause of the collapse. At the ceremony of notifying Governor Marshall of his

* *Proceedings*, Am. Soc. C. E., March, 1913.

† *Engineering News*, July 10th, 1913, p. 90.

selection as Democratic candidate for Vice-President, which took place in Indianapolis in August, 1912, a grand-stand containing several hundred people gave way. Fortunately, no lives were lost, and the incident was passed over briefly by the press; but, here again, one may imagine movements in such a crowd, inspired by political enthusiasm, which might have much greater effect than the mere dead weight. Mr. Tilden.

These are simply reports of facts, serious facts, involving the loss of many lives and the endangering of many more. It would be an easy matter to multiply instances, for scarcely a month passes that some accident of the kind is not reported. It is difficult, of course, to establish any direct and unquestioned connection between them and the subject of the paper. We naturally look for weakness in the structure rather than for excess in the load; but a more general recognition of the possible effects of motion in crowds would, the writer believes, result in safer and more rational design. Even practical builders, who might not be able to compute stresses and strains, would quickly "sense" the new requirements and build accordingly.

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TIDAL PHENOMENA IN THE HARBOR OF NEW YORK.

Discussion.*

By H. de B. Parsons, M. Am. Soc. C. E.†

H. de B. Parsons, M. Am. Soc. C. E. (by letter).—The writer is pleased to note the close approximation between the percentages obtained by Mr. Hazen in 1906 and those shown in the paper, as indicated in Table 31. Mr. Parsons.

Referring to Mr. Hazen's criticism of Table 32, the writer is of the opinion that the dips in the curves for February are due to the salinometer readings being taken throughout the year 1909 and used in connection with the average monthly discharges of the rivers. If salinometer readings could have been taken for as many years as the stream-gauging record, the diagrams shown in the paper would have had smoother curves, and the corresponding tables would have shown less variation from month to month. It happened that February, 1909, was a month of great river discharge, and March, 1909, a month somewhat below the normal.

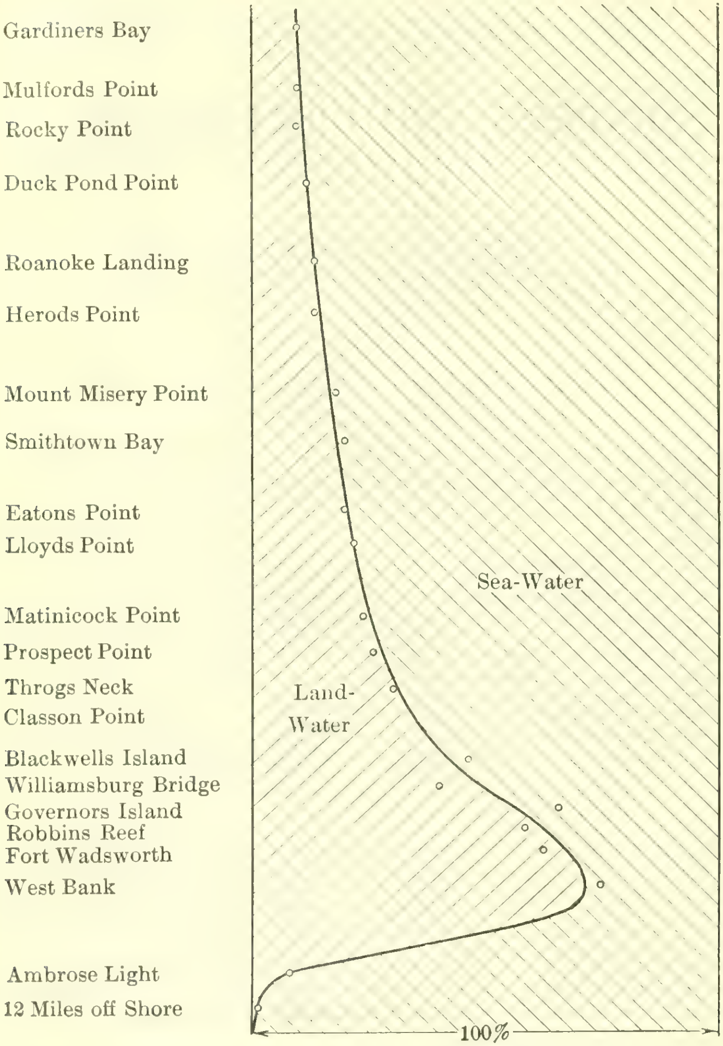
Mr. Hazen refers to an assumption made by the writer. This assumption, more correctly speaking, is a condition, namely, that the resultant flow of water passing any section, such as The Narrows, during each month, is the same as that of the land-water discharged during such month. The resultant flow is the difference between the ebb and flood volumes. This condition is self-evident. The only variation is the resultant flow of the East River, as explained in the paper, which will affect The Narrows.

Mr. Allen refers to a series of salinometer readings extending from the eastern end of Long Island Sound through the East River and Upper Bay. Fig. 66 shows graphically the results of these salinometer readings and the proportions of sea-water and land-water.

* Continued from August, 1913, *Proceedings*.

† Author's closure.

Mr. Parsons.



PROPORTION OF SEA- AND LAND-WATER
THROUGH LONG ISLAND SOUND AND NEW YORK HARBOR,
APRIL 13TH AND 15TH, 1909.

FIG. 66.

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THE ELEVATION OF THE TRACKS OF THE PHILADELPHIA GERMANTOWN AND NORRISTOWN RAILROAD PHILADELPHIA, PA.

Discussion.*

BY MESSRS. GEORGE S. WEBSTER, AND SAMUEL TOBIAS WAGNER.†

GEORGE S. WEBSTER, M. AM. SOC. C. E. (by letter).—During the past twenty-five years, grade crossings in the City of Philadelphia have been abolished by the co-operation of the City with the railroad companies. Mr. Webster.

An Act of the General Assembly of the State of Pennsylvania, approved June 9th, 1874, authorizes cities and towns of the State to enter into contracts with railroad companies, whereby the lines of railroads may be relocated, reconstructed, or elevated, with the view of abolishing grade crossings and furnishing better railroad service.

Under authority of this general act, city ordinances are passed, authorizing the mayor to enter into such contracts with railroad companies on whose lines it is desired to abolish grade crossings. These ordinances are not general, but apply to the particular line of railroad on which the work is to be undertaken.

The Department of Public Works conducts the negotiations with the railroad companies, prepares the ordinances, in co-operation with the same, has charge of the preparation of plans and contracts for changes of streets and other municipal work, and exercises the right of general supervision and inspection of all construction.

There is no absolute rule which can be laid down as to the best solution in matters of the depression or elevation of railroad lines. It will depend on the physical condition and the character of improvement of the section through which the line passes.

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* Continued from August, 1913, *Proceedings*.

† Author's closure.

Mr. Webster.

In the abolishment of grade crossings in Philadelphia the method adopted in every case has been one which seemed to suit best the particular problems under consideration.

Practically all the passenger-carrying lines have been elevated or depressed, the exception being branch lines carrying purely local traffic. The lines of the Philadelphia and Reading Railway Company and the Pennsylvania Railroad Company enter their terminal stations over elevated tracks. The Baltimore and Ohio Railroad Company enters its station by tracks depressed below the streets.

Generally, the elevation of the tracks is preferred by the railroad companies, but the depression is somewhat more to the advantage of the City, as the railroad is practically concealed, though the nuisance caused by smoke is greater than with an elevated line.

As a rule, the noise from a depressed line is much less than from an elevated line, and where the streets pass below the railroad there is more temptation for the commission of nuisances than where the streets pass overhead in the open.

The method which seems to affect property most seriously is that which involves a partial elevation of the tracks and a partial depression of the streets, in which cases the adjoining property is damaged to a considerable extent by the change of grade of streets, and a long time usually elapses before these properties recover their value and desirability.

The State of Pennsylvania does not contribute to work of this kind. It has been the general practice for the city and the railway company interested to pay equal proportions of the cost, although this is not an invariable rule. In only one instance has the street railway company contributed.

The work of abolishing grade crossings in Philadelphia commenced about 1887, and since that time three grade crossings of important railway lines have been abolished and about one hundred and twenty street and railway grade crossings have been eliminated.

The first ordinance authorizing the abolishment of grade crossings was approved on March 29th, 1887. This provided for the gradual abolishment of grade crossings and the opening of new streets along the New York Division of the Pennsylvania Railroad, in the northeastern section of the city. The Railroad Company elevated its tracks approximately 9 ft., and the grades of the streets were depressed a like amount, so as to permit of the construction of undergrade bridges. The Railroad Company paid the cost of changing the elevation of the tracks, the construction of the bridges, and all work incident thereto within its right of way. The City graded the street approaches to the bridges and paid the damages to property due to the change of street grades. The work has extended over a considerable period of years, and is not yet entirely completed, therefore the ultimate cost to the

City or the railway companies has not been determined, but when the agreement was entered into it was estimated that the cost of the work would be approximately equally divided. Mr. Webster.

An ordinance of December 26th, 1890, provided for the construction of the Reading Terminal Railroad to Market Street, by an elevated line from Green Street and the abolishment of grade crossings at Columbia Avenue and at Broad Street and Lehigh Avenue, those streets being carried above the railroad. The Railway Company paid all the cost of these improvements and changes.

An ordinance of February 4th, 1892, provided for the abolishment of grade crossings of the North Pennsylvania Railroad and the Connecting Railway Company, together with four grade crossings of streets, at a cost of \$300 000, \$200 000 being paid by the City and \$100 000 by the Pennsylvania Railroad Company, lessee of the Connecting Railway. The Philadelphia and Reading Railway Company, lessee of the North Pennsylvania Railroad, did not contribute.

In abolishing the grade crossings on Pennsylvania Avenue, under the ordinance of March 17th, 1894,* the railroad was depressed below the streets and carried partly in tunnel. Seventeen grade crossings were abolished, at a cost of \$5 487 000, the cost being equally divided between the City and the Railway Company.

Under an ordinance of 1897, thirty grade crossings were abolished on the Philadelphia and Trenton Railroad. In this instance the railroad was elevated in such a manner that street grades were not disturbed. The City contributed \$800 101 toward the cost of the work and the Pennsylvania Railroad Company, lessee of the Philadelphia and Trenton Railroad, paid the remainder, amounting to \$667 541.60.

An ordinance of 1900 provided for the abolishment of four grade crossings on the line of the Chestnut Hill Branch of the Philadelphia and Reading Railway. In this case the contract price was \$216 000. The City appropriated \$70 000 and assumed the liability for land damages, which amounted to \$82 035.75, making the total cost to the City \$152 035.75. The Railway Company paid the remainder, \$146 000.

The elevation of the tracks of the Philadelphia, Germantown and Norristown Railroad, authorized by ordinance of October 13th, 1906, which has been described so fully and clearly by Mr. Wagner, involves an expenditure of approximately \$7 000 000. The cost of elevating the tracks in order to give the railway company "as good accommodations and as complete and convenient facilities as existed prior to the commencement of the work, for conducting business and operating said railroad," was borne equally by the City and the Railway Company, the Railway Company bearing the expense of all betterments to its line.

The Philadelphia Rapid Transit Company (operating the street

* Described in *Transactions*, Am. Soc. C. E., Vol. XLIV, p. 1, and Vol. XLVIII, p. 470.

Mr. Webster. passenger railway system of the city) contributed $400 000 to the City as a part of the cost of abolishing grade crossings in this instance.

In the work of abolishing grade crossings described in Mr. Wagner's paper it was necessary in several instances to lower the grade of a number of important streets in order to carry them under the railroad. The properties fronting on these streets were used for both manufacturing and residential purposes, and were of moderately high class; and, as some of the streets were important thoroughfares leading from one populous district to another and carried heavy traffic, the problem of adjusting grades was difficult. It was decided that on all main thoroughfares the gradients should not exceed 3%, and that on minor residential streets steeper grades, generally not exceeding 5%, would be permissible, and on this basis the street grades were established.

Where streets were depressed to carry them under the railroad, a total reconstruction of the sewer system was made necessary. This required the laying of new trunk sewers (in many cases with flat gradients) to distant points where outlets could be obtained. To prevent overflows in these depressions during heavy rain storms, the sizes of the sewers were designed with an ample factor of safety.

The writer heartily endorses Mr. Wagner's statement that one of the most important features in water-proofing is to get the water away from the structure as fast as possible. As all viaducts and bridges carrying the railroad over streets are required to have solid floor construction, it is important, not only for the maintenance of the steelwork, but also for the protection of pedestrians passing under the bridge, that care should be taken to water-proof the structure properly.

The City of Philadelphia has recently reached an amicable understanding with the Pennsylvania Railroad Company and the Baltimore and Ohio Railroad Company for the abolishment of grade crossings and the readjustment of their freight lines in the southern section of the city, the cost of which is estimated to be about $20 000 000, which, under the terms of the tentative agreement, will be paid for approximately one-half by the City and one-half by the Railroad Companies. The City's contribution in this case is predicated upon the Railroad Companies agreeing that the railroad, to be constructed around the southern section of the city, to replace the existing lines, shall form an "Open Gateway" for the entrance of other railroads into the city, on the payment of an equitable share of the costs.

A minimum clearance of 14 ft. is required under all bridges carrying railroads above streets, whether or not occupied by street railroad cars, but it has been found that a greater clearance is desirable on wide avenues, even at an increased cost.

There has been little or no difficulty in obtaining the co-operation of the railroad companies in this work. Negotiations sometimes move slowly, on account of legal and financial obstacles to be overcome,

but, as a rule, the companies are as anxious to abolish their grade crossings as the City is to have them do so, and the work has been planned so that both railway and highway travel has been maintained during construction. In all cases the total cost, including land damages, has been less than the engineers' estimates prepared prior to the commencement of the work. Mr. Webster

Samuel Tobias Wagner, M. Am. Soc. C. E. (by letter).—Replying to Mr. Snow's questions, the abolition of these grade crossings had been under discussion between the City and the Railway Company for a number of years prior to the beginning of the work and was the result of a number of conferences terminating in the passing of the ordinance by the City Councils and the signing of the agreement, authorized by the ordinance, by the officials of the City and the Railway Company. During this time the general plan, as finally constructed, was decided on, and the scheme for the division of cost, as well as the necessary legislation required by the City to carry on its part of the work, was perfected. Mr. Wagner.

The ordinance, while general in its scope, covered some points with considerable detail, such as fixing the limits of the four-track viaduct; the main points of the railroad construction in which the City would join; and some specific details of what were to be considered as betterments for the Railway Company, such as the cost of the construction of two tracks of the steel viaduct between Brown Street and Girard Avenue, where the Railway Company had but two tracks prior to beginning work and where it was desired to have four in the completed work. The majority of the cases in which the division of cost had to be determined, was decided on after the work was completely planned and placed under contract. This was done after the most careful preparation of plans and estimates, based on accurate and checked data, as to the dimensions and character of the structures existing before the work was started. Conferences on each subject were held, and the matters decided on were made of final record by the signatures of the Director of the Department of Public Works of the City and the Chief Engineer of the Railway Company, who were the specially designated officials under the terms of the agreement. In this way, before any payments were made on a contract executed by the Railway Company, the amounts to be paid by each interest were definitely determined. As the ordinance did not provide for any betterments to the City, the division of the estimates on the contracts executed by the City was always into two equal shares.

Where streets were widened, the Railway Company paid for one-half of the cost of the widening. This widening was shown on the general plans of the work, which were made part of the original agreement.

Mr. Wagner.

The agreement specially provided that the Railway Company could not recover for damages, caused by changes of the grades of streets, to any of its property held prior to the date of the ordinance, and, therefore, whatever amount was necessary to place the property in usable condition was divided equally between the two interests. This work was always done under contract on properly approved plans.

The question of the design of the temporary trestle was one which required much study in order to determine the most economical construction combined with its maintenance under heavy and rapid travel. One of the requirements of the Operating Department was, that there should be, at all times, two tracks entirely unobstructed, on which all trains could be run on schedule time. This meant that a perfect track must be maintained, and the primary thought in the design was that of minimum maintenance. As one of the two tracks carried by the trestle was half supported by the masonry wall, and as a portion of it was over a part of the excavation for the foundations, it was considered wise to endeavor to have a specially secure footing for the remainder of the trestle. The section of the work where the trestle was built was formerly occupied by four tracks, 12-ft. centers, on a right of way 66 ft. in width, with drainage ditches on the sides, and was not on a street surface. The bottom of the foundation of the concrete footing was but 12 in. below the old low-level rail, and therefore not down to the original sub-grade. It is believed that any increased cost in the placing of this concrete was more than offset by the saving in maintenance. In one or two cases where the footings were on a fill, and where settlement had occurred, the maintenance of the track by blocking up the stringers was very expensive on account of the continuous traffic.

Mr. Harte's remarks about the water-proofing of the bridges are interesting as being further proof of the perversity of water in finding its own way and not following one which has been provided by the engineer. As already explained, the use of drainage nipples was found to be bad, and the troughs on later designs were entirely filled with concrete and the mastic placed on top. The grades were either toward both ends of the span, or all to one end, depending on the grade of the track. The only difficulty with this method is that if the sub-drainage, behind the back walls, is not good, the water, in case of a heavy rainfall, will back up, and it is difficult to prevent it from working under the apron-plate and down the face of the abutment. Further, it is often difficult to get sufficient grade on even a short span to carry the water off the bridge as rapidly as is desired, especially after the ballast has become dirty. In recent designs, the detail arrangement of the steel above the top of the floor has been made with special reference to the water-proofing, and the principle has been established that it is not wise to allow the water to run off the ends of the span. It should be caught by inlets placed near the ends and

carried into the sewers by wrought-iron piping with suitable clean-outs. Intermediate inlets are also provided on the concrete floor, with grades as steep as possible. In these designs the membrane method of water-proofing was adopted as being preferable to the asphalt mastic. In a number of spans of this character just completed, the wisdom of this method seems to be indicated as the results so far have been very good. Mr. Wagner.

It will be noticed that the majority of the bridges described in the paper were water-proofed with a natural rock asphalt mastic, without any protection from the ballast. In spite of what would be now considered indifferent details, these bridges are giving fairly satisfactory service, and to the writer's knowledge, there has not been a single complaint from any one as to leakage. It is true that they are not all tight, but the average seems to be good. When it is remembered that there are more than 350 000 sq. ft. of bridge surface over streets, or more than 8 acres in all, it is believed that this is a fair record, when the usual ability of the public to complain, is considered.

The question of the proper material for use in the water-proofing of solid floor bridges is a most interesting one, not only on account of the cost involved, and the uncertainty of the durability of the materials, but also because there are two widely different materials in very general use for such work, namely, coal-tar pitch and materials of an asphaltic nature, and it behooves the engineer to use the best. The whole question is also complicated by the proper design of the steelwork for the water-proofing, as well as the workmanlike application of the materials, both of which are of the utmost importance. With careful observation during the past four years no cases have been discovered where the asphalt mastic has been cut into by the ballast in such a manner as to injure it in any way, and considering the large areas involved, there have been very few cases of the mastic cracking on the main surfaces. Where cracks have occurred, they have generally been along the webs of the girders or at the ends of the spans, and even these have been surprisingly few. In new work where the **V**-shaped wedge of pure, low melting point asphalt has been used along the girders, there has been no cracking or leaking. In asphalt mastic, the writer believes that the use of a ductile, low melting point asphalt as a flux is desirable, and also that the proportions be such as will produce a mastic which is soft rather than one which is hard.

During the summer of 1913, asphalt mastic, made of Val de Travers natural rock, was uncovered on a brick-filled arch carrying a railroad over a street in Philadelphia. The arch had been built by the City in 1892. The mastic was 1 in. thick and placed on cement mortar over the top of the brick. The dry stone packing for drainage was placed immediately on the mastic. Inspection showed that in many cases the stone had cut down into the mastic, but in four openings made at

Mr. Wagner. different parts of the bridge, every case of such cutting showed sufficient mastic remaining to give adequate protection. At the end of 21 years of service, the surfaces of this mastic were bright and showed no signs of disintegration of the asphalt. A small sample removed showed surprising ductility and uniformity of the fractured surface.

Replying to the question asked by Mr. Lewis, comparisons between the original estimates of the total cost of any work and the final cost are always interesting, and of great value to the engineer who has much of this kind of work on which to estimate. In this case, it is possible to give but rough figures at the present time, for though the work of construction is completed, there are a number of suits for damages which are still pending, and until these have been disposed of, final figures cannot be given. It is quite safe to state, however, that the work will be completed well within the original estimated cost of $7 659 740, as at the present time the total expenditures amount to about $6 800 000, and the total amount of the unsettled claims is far less than the difference.

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THE STORAGE OF FLOOD-WATERS FOR IRRIGATION: A STUDY OF THE SUPPLY AVAILABLE FROM SOUTHERN CALIFORNIA STREAMS.

Discussion.*

By Charles H. Lee, Assoc. M. Am. Soc. C. E.

Charles H. Lee, Assoc. M. Am. Soc. C. E. (by letter).—The author has presented in a very detailed and interesting manner the water supply situation on the San Gabriel River, and the writer agrees heartily with his conclusions regarding the possibility of increased use of the flow of Southern California streams by storage. The subject is one that offers an interesting field for engineering endeavor, and the author has laid the foundation for a broad discussion which should be of great value, not only to the Engineering Profession, but also to the inhabitants of Southern California. Mr. Lee.

The writer has been familiar with the water resources of Southern California for a number of years, and during the past year has had occasion to make detailed studies of three important streams, in connection with proposed increased use of the surplus flood. He has been impressed with one phase of storage in this region, which, although mentioned by Mr. Strong, was not particularly emphasized. This is the necessity for over-year storage in addition to monthly regulation, in order to accomplish the greatest beneficial use of stream flow. Mr. Strong has approached the subject with the primary idea of making increased use of the stream flow by regulation of monthly inequalities. The writer believes that permanent increased use of the surplus flow of Southern California streams requires the regulation of annual run-off as well as monthly flow.

* This discussion (of the paper by A. M. Strong, Assoc. M. Am. Soc. C. E., published in May, 1913, *Proceedings* and presented at the meeting of September 3d, 1913), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

Mr. Lee. The necessity for over-year storage is well shown by Table 3, which gives the total discharge of San Gabriel River for the 12-month season, September 1st to August 31st, from the seasons 1895-96 to 1910-11, inclusive, as observed by the United States Geological Survey. It will be noted that during these 16 years the annual run-off has varied from a minimum of 9% of the mean to a maximum of 305%, or from one-tenth to three times the mean. Considering groups of three consecutive years, the extremes have been from 14 to 216%, or from one-seventh to more than twice the mean. The run-off during the 7-year period, 1897-98 to 1903-04, was only 37% of the mean, though that of the following 7 years averaged 176 per cent. Although the 3-year period of drought, 1897-98 to 1899-1900, is of infrequent occurrence, and might be tided over by temporary expedients, yet the benefit to be derived from annual storage is great, and the permanent increased use of stream flow cannot exist without it.

TABLE 3.—Total Annual Discharge of San Gabriel River.
(Compiled from U. S. Geological Survey Records.)

Season, September 1st to August 31st.	Mean, in second-feet.	Acre-feet.	Percentage of mean.
1895–96	38.9	28 200	25
1896–97	126.4	90 500	79
1897–98	32.9	23 700	21
1898–99	13.8	9 900	9
1899–00	16.7	12 100	11
1900–01	137.0	95 400	82
1901–02	33.9	24 500	21
1902–03	145.3	104 800	92
1903–04	40.7	29 600	26
1904–05	220.3	158 700	139
1905–06	320.6	235 100	205
1906–07	483.9	349 200	305
1907–08	109.3	79 300	69
1908–09	254.3	179 500	157
1909–10	192.3	139 900	122
1910–11	376.0	271 600	237
Mean	158.9	114 500	100

The determination of dependable supply with over-year storage regulation is easily made by constructing a mass-curve of daily discharge in acre-feet for the period of record. The ordinate to this curve at any date represents the aggregate run-off from the initial date of record to the date being considered, and the slope of the curve represents the rate of flow. The mass-curve can be constructed either for the full flow of the stream or for that portion which a transmission system of given capacity will divert. From such a diagram the safe yield of a given reservoir with the known water supply can be determined with precision, or, if desired, the storage capacity necessary

Mr. Lee.

for a given draft on the known supply. The writer has found such a curve to be the simplest and most comprehensive form in which to assemble the run-off data of a stream for solving the problems discussed by Mr. Strong, and suggests it as a more satisfactory method of ascertaining the supply available for storage than that used by the author.

The general absence of good reservoir sites of adequate capacity in the mountains eliminates the possibility of surface storage on most Southern California streams. Furthermore, surface storage is not desirable on account of the great evaporation loss. A reliable 4-year record of evaporation from a pan floating on the surface of Sweetwater Reservoir near San Diego indicates an annual depth of 58.7 in., amounting to about 40% of the annual storage. The conditions throughout the valley portions of Southern California, away from the Coast, are similar to those at Sweetwater Reservoir. The losses resulting from extended over-year storage in surface reservoirs in the valleys of Southern California, therefore, would tend to offset the benefit.

Underground storage possibilities in the gravel-filled basins which underlie these valleys have all the conditions necessary for efficient annual regulation. The storage capacity is almost unlimited, the evaporation losses outside the region of outlet are small, and the movement of water through the gravels to the region of outlet is so slow that annual as well as monthly irregularities of supply are smoothed out. This type of storage is being practised on several streams of the region with good results and promises eventually to solve satisfactorily the problem of annual storage.

The common practice of saturating the gravels of the middle or lower portion of a basin does not accomplish over-year storage, however; it merely raises the local ground-water surface temporarily, and the water soon reaches the region of outlet and is lost by evaporation or overflow into surface streams before a dry year arrives. The best practice is to get the water into the gravels around the rim of the basin, close to the mountains. The storage capacity is greatest here, the water levels are raised throughout the basin, and a greater time elapses before the water can reach the region of outlet, thus maintaining the water levels more permanently. Storage water carried out on these lines will do much toward greater use of the flow of streams like the San Gabriel River.

The results accomplished by underground storage or "water spreading" on the alluvial fan of the Santa Ana River in San Bernardino Valley have come under the writer's observation. This stream had an annual run-off, during the period of 1900-01 to 1911-12, according to the Government record, of 72 100 acre-ft. There is a surface storage reservoir of 26 463 acre-ft. capacity on the upper portion of this stream, which recently was increased to 65 000 acre-ft. With this regulation

Mr. Lee. the loss of surplus water amounts to 42% of the total run-off, while for the San Gabriel it is 64%, as indicated by Mr. Strong's data (Table 4). The conservation of this surplus by water spreading has been attempted for a number of years on a small scale, but during the last four seasons it has been placed on a permanent basis. From 10 000 to 15 000 acre-ft. annually are now being diverted and stored in the gravels of the San Bernardino Valley, of which about three-fourths are derived from Santa Ana River, thus reducing the lost surplus flow of that stream from 42 to 30% of the total run-off. The annual cost of this work is about 30 cents per acre-ft. stored, including operation and interest on investment. The quantity of water stored could be increased considerably with very little additional expense per acre-foot.

TABLE 4.—DISCHARGE OF SAN GABRIEL RIVER AVAILABLE FOR CANALS AND SURPLUS.

(Prepared from Author's Data.)

Season.	Total discharge, in acre-feet.	Discharge available for canals, in acre-feet.	SURPLUS.	
			Acre-feet.	Percentage of total.
1902–03	104 944	33 000	71 944	68
1903–04	29 650	24 500	5 150	17
1904–05	159 128	36 750	122 378	77
1905–06	234 776	44 050	190 726	78
1906–07	349 540	49 950	299 590	86
1907–08	83 200	47 550	35 650	43
1908–09	179 850	43 720	136 130	76
1909–10	140 040	43 730	96 310	69
Average......	160 140	40 400	119 740	64

In connection with the subject of natural underground storage, the writer has had occasion to make careful and extended measurements of percolation from gravel stream channels in Owens Valley, and has found that, for stable channel conditions, a straight-line relation holds between loss in second-feet per mile of channel and total discharge (Fig. 20). Although, as the author states, the measurements of absorption on the San Gabriel River by the United States Geological Survey are not satisfactory, yet on other Southern California streams the data are more complete. Analysis of these data indicates that the straight line holds for percolation from the gravel stream channels of Southern California, for moderate discharges, where channel conditions are fairly stable (Fig. 21). The conditions on the Santa Ana River correspond closely to those on the San Gabriel, and give an idea of the extent to which absorption occurs through natural processes.

Mr. Lee.

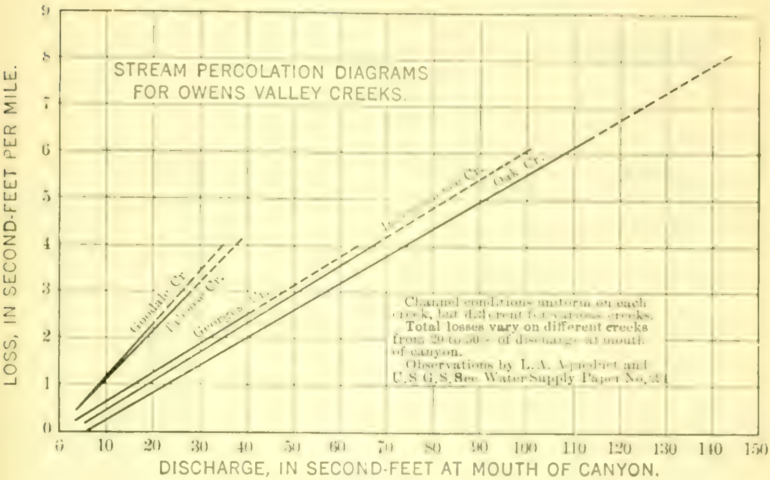

FIG. 20.

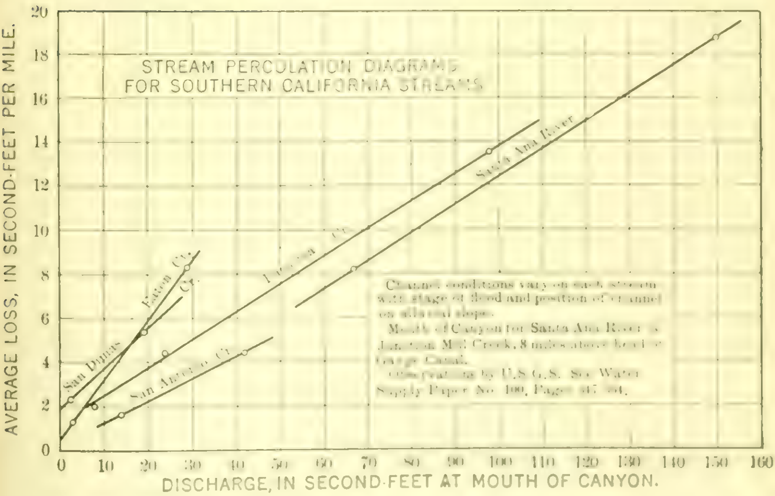

FIG. 21.

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MODERN PIER CONSTRUCTION IN NEW YORK HARBOR.

Discussion.*

By Messrs. E. G. Walker, Edwin J. Beugler, and Harrison S. Taft.

E. G. Walker, Jun. Am. Soc. C. E. (by letter).—The Engineering Staff of the Department of Docks and Ferries of New York City, has evolved a novel and effective type of pier, without introducing any drastic departures from generally accepted methods of construction. Composite structures in which reinforced concrete is used are common, but a reinforced concrete decking on a timber pier, as detailed in the paper, is less common, and, in many cases, would need special justification by reason of the great difference which generally exists between the life of a concrete work and that of a timber structure set in water. In New York Harbor, however, there is a special combination of conditions, which, as a rule, does not occur elsewhere, and makes the composite piers described an admirable solution of the problem of providing wharfage space economically. Mr. Walker.

The figures in Table 1 show an appreciable saving in first cost by the adoption of the new construction, but no direct figures are given as to the relative maintenance costs. Inasmuch as reduction of the latter cost is often of greater importance than a small saving on first cost, the writer has endeavored to arrive at some relative figures from the data in the paper. From Table 1, he has obtained by deduction the figures in Table 2.

The author claims that, with the concrete and asphalt decking, repairs to sheathing and decking are practically eliminated, and that repairs to rangers and caps are reduced considerably. This gives the approximate figures in Table 3.

* This discussion (of the paper by Charles W. Staniford, M. Am. Soc. C. E., published in May, 1913, *Proceedings*, and presented at the meeting of September 3d, 1913), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

Mr. Walker.

TABLE 2.—REPAIR COSTS OF WOODEN DECK PIERS.

Description	Percentage of total original cost.	Number of years required for complete renewal.	Percentage of average annual cost of renewal.
Sheathing	12	6	2.00
Backing log	1.8	8	0.23
Fender chocks, including vertical sheathing	4	10	0.40
Fender piles	4.7	12	0.40
Decking	11.3	15	0.75
Bracing	7.1	40	0.18
Rangers and caps	24.4	40	0.61
Piles	34.7	60	0.58
Total annual cost of renewals, averaged over 60 years			5.15

TABLE 3.—REPAIR COSTS OF CONCRETE DECK PIERS.

Description.	Percentage of average annual cost of renewal.
Sheathing and decking	0.05 (say)
Backing log	0.23
Fender chocks, etc	0.40
Fender piles	0.40
Bracing	0.18
Rangers and caps	0.50 (say)
Piles	0.58
Total annual cost of renewals, averaged over 60 years	2.34

This total is only about 46% of the total annual cost of maintenance of the timber-decked piers, considering only equal capital expenditure. Inasmuch as the average cost per square foot for timber-decked piers is \$1.07, and for concrete-decked, \$0.97, it follows that the average annual costs per square foot for maintenance are:

For wooden deck piers.........\$1.07 $\times$ 0.0515 = \$0.055
For concrete deck piers........\$0.97 $\times$ 0.0234 = \$0.023,

showing a reduction of 58% by the use of concrete.

If this deduction is correct, it is obvious that a very great economy may be effected when large areas of timber piers have to be dealt with.

One feature of the composite pier construction has been omitted by the author, apparently owing to the fact that sufficient time has not yet elapsed to enable the requisite experience to be obtained. The necessity for fairly frequent reconstruction and removal of piers, or portions of them, is emphasized in the paper, but it is evident that the demolition of a reinforced concrete decking, though probably less troublesome than the removal of reinforced concrete piles and bracing.

is still a considerably heavier and more expensive undertaking than the removal of timber decking. In cases where there is much chance of alteration of arrangements this might reduce very considerably the economy obtained by the use of composite piers. The writer would be glad to learn whether there are any data on this subject. Mr. Walker

Possibly additional economy might be obtained by reducing the deterioration of the piles. In Table 3 it will be seen that renewals to piles form the largest item, namely, 0.58% per annum. It may be presumed that, as the destructive agency of marine boring insects is absent, the main deterioration of the piles is the decay which takes place on the alternately wet and dry surfaces between the extremes of tidal range. It might be worth considering whether a saving could not be effected by casing old piles in concrete for a sufficient length to prevent further decay. A casing of moulded concrete slabs, suitably reinforced and filled with concrete, can be fitted around a pile at very little cost, and is sufficient to retard almost indefinitely its deterioration. This method has proved effective in a number of instances.

Edwin J. Beugler, M. Am. Soc. C. E. (by letter).—As literature on pier construction at American ports is somewhat limited, and engineers are frequently in the dark as to practice at the larger shipping centers, this paper will be appreciated by those having to do with the construction or maintenance of wharves and piers. American engineers have been criticized frequently for the adoption of what appears to be a temporary expedient in the way of shipping facilities, even at the larger ports. The analysis given in this paper will explain many of the questions as to why the particular type of pier construction commonly used in New York Harbor was adopted. Mr. Beugler.

New York City is unique in regard to local conditions which favor the use of timber in the construction of piers. Though the cost of timber has been advancing from year to year, and will continue to do so until the figure reaches a point where other materials will have to be used from an economic standpoint, the substitution of concrete for the deck of the pier has enabled the cost per square foot to be kept within the limits of that of the former structure built entirely of wood. At the same time considerable economy has undoubtedly been secured, as far as maintenance costs are concerned.

It seems to the writer that still further economies in maintenance costs might be secured by the use of creosoted timber piles and caps, in order to avoid the renewal of the upper portion of the untreated piles and to maintain a fairly stiff structure. There is a possibility that bench-capping throughout the structure may weaken its resistance to impact from vessels striking the pier. Another advantage to be

Mr. Beugler. secured by the use of treated timber would be insurance against the action of sea worms.

Fortunately, at the present time, New York is surrounded by water, the impurities in which do not permit the *Teredo navalis* or other sea worms to exist. Conditions may change, however, and, in the East River particularly, much harm might result from the removal of sewage and other waste which keep the water impure. The great quantity of fresh water existing in the North River would probably make the danger from worms more remote, even if the impurities were largely removed. The writer believes that this explains why timber piles are not affected in the immediate vicinity of New York. An experience which he had some years ago on railroad construction work along the Connecticut shore showed that yellow pine timber could not be kept intact much longer than one year. Certain piling was removed fourteen months after it had been driven and, with the exception of a core in the center of the piles about 4 in. in diameter, was found to be riddled by worms. This would seem to show that but for the impurities in the water, the same thing would take place in the untreated timber piers in New York Harbor.

The adoption of all-concrete piers is probably quite remote for New York. The uncertainty as to the life and durability of plain or reinforced concrete piles in sea-water makes it inadvisable to invest a large amount of capital in such structures until their durability is proved beyond a doubt. At the present time, it is believed that if impermeable concrete can be secured, there will be little or no question of durability, but practically it is almost impossible to secure this class of work. The question of rigidity and the inability of a concrete structure to withstand shock seems to be a serious one, but not unsurmountable. Some of the concrete piers constructed along the Pacific Coast and elsewhere have special provision for absorbing the impact. One scheme, which appears to have worked fairly well, consists of a number of steel springs quite similar to those used in freight car construction, placed along the edge of the deck, with a long distributing timber instead of the usual fender construction. At other places the concrete construction has been faced with a line of spring piles arranged so that the piles absorb the shock before the bearing comes directly against the concrete deck. Even with the timber type of pier construction, it is quite necessary to secure a rigid structure, particularly where the pier is covered by a permanent superstructure of some size.

One interesting point brought out by the author is the development of the water-front from a distinctly business standpoint, that is, on the basis that all expenditures for improvements shall return a reasonable rate of interest on the investment. This has not always been the rule in the case of expenditures for public works, for which funds are apparently more easily secured than for private enterprises.

Harrison S. Taft, Esq. (by letter).—Mr. Staniford's invitation to present a written discussion of this valuable paper is accepted by the writer, perhaps with a little hesitation, as he feels that he may be "rushing in where angels fear to tread." A full discussion of the concrete dock problem would be so extensive and would lead into so many phases that it would be impossible to cover the subject thoroughly in a single article. Mr. Staniford treats of only one special phase of the problem. For several years the writer has been making a deep research and study of the whole subject, not only as developed in foreign countries, but as worked out thus far in domestic construction. The results of this research are being compiled into a rather extensive treatise or paper to be entitled "Concrete Docks," but as it is impossible to make the entire results of this research a part of this discussion, the writer will state simply a few of the facts, as therein recorded, in order to bring out the different phases of the subject. Mr. Taft.

Those who have studied the subject are no doubt aware that the first and most important question that confronts the engineer is the practicability of using concrete in sea water. There can be no denying the fact that, in attempting to make such use of concrete, there have been many disastrous failures. These have been due not as much to the design of the structure as to the use of unsuitable material and improper methods of placing the concrete, on which too much stress cannot be laid.

For structures in sea water, the whole subject reduces to the importance of obtaining a cement which possesses the inherent property of resisting the disintegration due to the chemical action of magnesium, and the sulphate contents of ocean water, on the alumina compounds in the cement; and also of obtaining an impermeable concrete without the use of any of the so-called water-proofing compounds. Such a cement must be low in alumina and high in silica; it should be of a slow-hardening but quick-setting type, and also of a fine pulverization, with no free lime. From the great success obtained by the use of foreign cements in structures placed in sea water, it is very evident that the German manufacturers solved this important question long ago. From the large number of various ideas of which one reads in American technical papers, it would appear that the manufacture of a domestic cement suitable for use in sea-water concrete is in the embryonic stage, the ideas as to the facts of the question being almost as numerous as the different brands of cement.

Although to the average concrete engineer the chemical composition and physical structure of the stone, sand, and gravel for use in proposed sea-water concrete structures would seem to be of minor consequence, it is a fact that such questions must be given the greatest consideration, if such concrete is to be of a lasting quality. It is of the utmost importance that such a concrete should have a maximum

Mr. Taft. density. Thus the mechanical combination of the sand, stone, or gravel should be known, and modified to suit conditions as the work progresses. Far better results will be obtained by using a hard trap rock than gravel.

The next phase of the subject that confronts the engineer is the design. In designing a new type of structure one naturally investigates first what others have done along similar lines. Generally speaking, in America the problem is in a very early stage, as it is only natural that a forested country should be the last to take up the development of concrete docks. When the extensive reinforced concrete docks in England, France, Spain, and other European countries are investigated, it appears that this class of construction passed the experimental stage long ago. Especially is this so in England, where the art has reached a degree of perfection far in advance of that in any other country; such a degree, in fact, as to have become almost a standard for other parts of the world. A review of the English concrete docks shows that some have been in successful operation for eighteen years. Their maintenance cost is reported to be exceedingly small. In France, Spain, Italy, South America, and other foreign countries, concrete docks are to be found, and their number is increasing rapidly. It is to be regretted that time will not here allow a detailed discussion of such an important part of the subject.

After the engineer has satisfied himself as to what has been done, the question of his own design stands out before him. There is no doubt in the writer's mind that the average concrete engineer is perfectly capable of designing concrete docks of one type or another which will more than fulfill the requirements for which they are intended; but, in making this design, the question is, what will be the cost of the dock? Thus the design problem reduces itself to a question of cost and the cost problem to a question of reducing to a minimum the quantity of concrete, reinforcement, and all other material, including forms, without diminishing the strength of the structure. This should give an arrangement of beams, slabs, or otherwise, which will result in a most economical and practical method of construction.

It is unnecessary to impress on the members of this Society the fact that the cost of the design for a structure is but little in comparison with that of the material that goes into it and the necessary labor incident to its construction. As an axiom, the most economical form of concrete construction is manifestly that in which all secondary stresses are reduced to a minimum and all material is performing its utmost duty.

The next phase is, what type of construction shall be adopted for the concrete dock, in order to comply with the foregoing truisms? Shall the dock engineer recommend a full, out-and-out, reinforced concrete and structural steel dock, as worked out at San Francisco

and later adopted by the United States Government for its concrete docks in the Philippines and Puget Sound Navy Yard? Or shall he recommend a driven concrete pile with concrete beam and slab-deck type of construction, so common in foreign countries and also found among American concrete docks to quite a large extent? On the other hand, he has the option of proposing a semi-concrete dock of either of two types: (1), wooden piling, plain, creosoted, or concrete protected, with a concrete deck; (2), reinforced concrete driven piles with a wooden decking. Right here Nature introduces another difficulty—the destructive teredo and other marine borers. Mr. Taft.

In fresh water it is perfectly feasible to adopt untreated wooden piles, with a concrete deck. In New York Harbor, as Mr. Staniford cites, this type of construction can be made a success because the sewage is destructive of the teredo in such waters; but, in the waters of the South Atlantic States, the Gulf States, the Caribbean Sea, and the whole Pacific Coast, conditions are met which have to be overcome by a different type of construction from that worked out so ingeniously under the author's supervision.

Another side of the subject is the comparison of wooden with concrete piles, with reference to load-carrying as well as cost and longevity. As a concrete pile will carry approximately three times as great a load as a wooden pile, and, under favorable conditions, can be put in place for about three times the cost of a creosoted wooden pile, would it not appear, in view of the possible long life of a concrete pile in sea water, that a semi-concrete dock—concrete piling and wooden decking—can be built at a reasonable cost compared with an out-and-out wooden dock? In other words, in teredo-infested waters, where a wooden pile dock has a life of about 15 years, a concrete pile dock will last, supposedly, for a whole generation, if not longer.

Though the chemical and engineering sides of the problem have their weight, the most important phase of the subject, in the final analysis, is finance. When a careful analysis of the relative value of initial cost, annual depreciation, fire insurance, bond issues, interest on bonds, and sinking funds is considered, the results are such as to astonish even those who perhaps may be well posted on other phases of the subject. Such an analysis will show that, whereas a wooden dock appears to be a most economical type with which to start, it soon becomes an expensive structure to keep in condition and carry all the overhead charges, especially if such a dock is built on a bond issue, the life of which exceeds the life of the dock, thus resulting in an overlapping bond issue in case the dock is rebuilt. The evils attached to such systems of financiering have been brought home most forcibly in connection with former paving work in New York City streets and with other public improvements. Until harbor development experts fully master the ins and outs of the financial side of the concrete

Mr. Taft. *versus* wooden dock problem, they have another step to take in perfecting themselves in their special line of work.

Perhaps the most interesting phase of the subject, as the writer looks at it, is the construction. As Mr. Staniford has dealt entirely with the designing side of the problem, the writer does not feel at liberty to go into this phase of the question. It is one in which no doubt many engineers are deeply interested.

With this general review of the whole concrete dock problem before him, it was with deep interest that the writer read Mr. Staniford's paper and studied the standard type of construction his department has evolved from the old-fashioned wooden pile, wooden deck docks, a process of true elimination, with each step tested carefully before taking the next one. As the author states that twenty-six such piers have been built during the last 7 years, and adds that they have behaved admirably, it leaves only a small loop-hole for injecting any adverse criticisms of a first-hand nature, as it was during the later stages of the construction period of the Chelsea piers that the writer had an opportunity of witnessing dock work in New York City, although previous to that time he had been a resident of New York and vicinity for about 10 years.

In studying the author's design, the writer could not help comparing it with the so-called Cattle Dock at Liverpool, constructed of wooden piles and wooden bracing, but with a concrete beam and slab decking. As Mr. Staniford states that his type of semi-concrete dock has not been generally adopted by other ports, it would seem that dock engineers hesitate to build a permanent structure on a more or less temporary foundation, especially temporary in teredo-infested waters, in spite of the many excellent qualities claimed for this type, as respects the Port of New York.

When the life of a wooden structure below the high-water line is not endangered by wood-borers, it is quite true that a wooden-pile, concrete-deck dock can be built for a most economical figure; but, how many of our important harbors are free from the wood-boring pest? It would be of interest to know the probable cost of Mr. Staniford's type of dock if the wooden part of the structure were replaced with concrete piles and if a concrete cap were used.

A feature in Mr. Staniford's illustration that attracted the writer's attention was the thickness of the concrete deck-slab, as, in general, it appears to be so nearly that of a well-known flat slab system. On the principle that a dock is a structure carrying heavy floor loads, it is essential to adopt a substantial type of construction. Still, the writer would like to ask the author whether it would not be possible to make his dock still more economical and just as strong by using a shallow type of beam with a wider bent spacing, on the lines of the so-called "Floretyle construction," thus bringing the design into ac-

Mr. Taft.

cord with the truisms and axioms previously stated? Or does he depend on his heavy concrete floor slab to obtain sufficient mass in his dock to help resist the lateral thrust from large steamships lying alongside? Not that the writer has any connection with the "Floretyle construction," but he is deeply interested in finding the greatest number of ways to reduce to a minimum the material needed in a concrete dock without decreasing its strength.

Another question: Would it not be possible to design a concrete pile dock with concrete caps and a shallow beam decking which would prove to be fully as economical as that shown on Plate LXXII, when such questions as depreciation, fire insurance, taxes, interest on investment, etc., are taken into consideration?

At first it would appear that the type of docks shown on Plate LXXII was lacking in cross-bracing, and that the lateral forces from the pounding of vessels would crack the concrete deck. As Mr. Staniford states that no cracks or other imperfections have as yet appeared, perhaps the heavy 10½-in. slab acts in such a way as to distribute any local lateral forces over a wide area. Still, the writer would be interested in seeing the results if one of the South Brooklyn docks were accidentally rammed by a steamer moving under one bell.

Mr. Staniford speaks of the objectionable feature of the rigidity in a complete concrete structure. If concrete possesses no elasticity, how does the flexibility of his wooden piles prevent the concrete deck from cracking under the force of a lateral blow from a vessel? As the author shows only a short length of piling on Plate LXXII, he gives no idea as to the depth of the water in which these semi-concrete docks are built, whether in shallow depth, with short unsupported lengths of piling and the slip dredged out, or whether the depth is uniform, such as 20, 30, 40, 60, 70, or even 90 ft., as in Seattle Harbor, and that, too, within 700 ft. of the bulkhead line. Such excessive depth might not give a dock of this type the same rigidity as obtained in the shallower harbors of the Atlantic Coast. Thus it might not be suitable for deep harbors.

Table 1 contains data of great value; it is the only statement of its kind the writer has found in his prolonged research. It would appear from this table that the average annual cost of maintenance and repairs for New York City docks is about 11% of their total cost. In Puget Sound waters, the annual depreciation of a creosoted pile dock is fixed by the valuation experts at 10% of its initial cost. In fresh water a depreciation of 5% is quoted. As good merchantable dock timber can be had, f. o. b. site, in Seattle for about \$15 or \$16 per thousand, with cement in carload lots at \$2 per bbl. at the site, a comparison of cost of an Eastern dock with a lumber dock built in Puget Sound waters is perhaps not exactly equitable. Again, New York docks do not need concrete or treated piles as do those in Puget

Mr. Taft. Sound. As the prices per square foot quoted by Mr. Staniford for the two South Brooklyn docks are practically the same as it is costing to build the new public docks (wooden creosoted piling and complete wooden decking) of Seattle for deep-draft ships, in view of the longevity of the New York type of concrete docks, the comparison is striking. It is the more remarkable because the under-water part of the South Brooklyn dock will last many decades longer than will the creosoted piles driven in the Puget Sound and other teredo-infested harbors.

Mr. Staniford states:

"The attempt at absolute permanency * * * has generally resulted in prohibitive first cost, when considered as a business proposition requiring interest on the capital invested."

He also says:

"It has resulted, in some instances, in absolutely permanent structures at such great expense that remunerative return on the capital invested is highly improbable, if not impossible; in other words, the benefits derived are being consummated at too great a cost, even when considered from the point of view of 'indirect revenue'."

It is perhaps true that when attempts have been made at absolute permanency at other ports than New York, the general result has been an excessive and perhaps prohibitive first cost, prohibitive in the past, except in our largest seaports. Still, full concrete docks have been built, and are still being built in some of our larger Pacific ports, as well as very extensively in foreign countries; but, what of the future? Has the concrete engineer reached the maximum economy in concrete dock design? If so, Mr. Staniford's statement can perhaps stand unchallenged. On this one point, if on no other, the writer desires to cross swords with the author of this valuable paper. It is a question which has been discussed frequently in the technical press of late, but all that discussion seems to be in connection with present and ordinary types of construction, and not along new lines of design—still trying to obtain economy by improving the reciprocating engine rather than by adopting the rotary type.

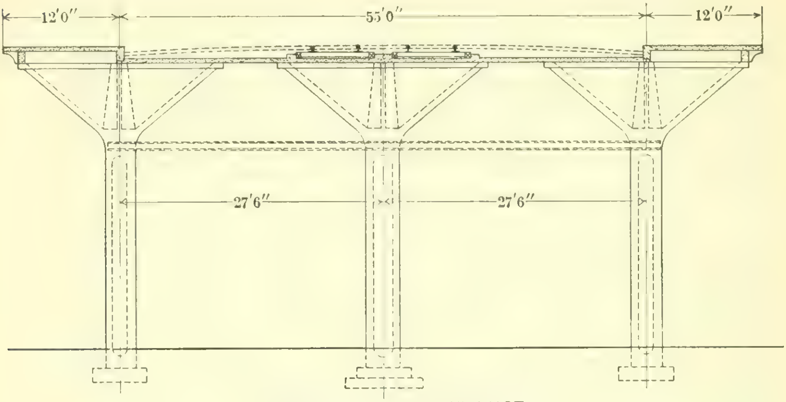
The writer does not wish to inject into this discussion anything that would detract from the interest and value of this paper; but, in compliance with a suggestion by Mr. Staniford, he submits some illustrations, indicating a method whereby it would appear that the maximum economy has not yet been reached in the author's design. An attempt will also be made to convince Mr. Staniford of the possibility of building a full concrete dock, the first cost of which will not be prohibitive. This will be done, not by filing a large number of plans covering various designs for concrete docks, but by submitting just one design wherein the quantity of material has been reduced to a minimum without any reduction in strength, as mentioned previously.

The most ordinary type of concrete construction is the well-known beam-slab system. In such a system the load on the floor is carried to the beams and thence to the supports. The upper three-eighths (approximately) of a concrete beam is in compression, the lower five-eighths (approximately) in tension. In designing reinforced structures, no account is ever taken of the tensile strength of concrete, the primary function of this material being to resist compressive and shear stresses. Steel is inserted to take up the tensile stresses. The concrete below the neutral axis is useful only as a means of holding the steel in position and making it act through shear. Thus it is apparent that more than one-half of the concrete in a beam is not utilized economically to its full capacity, and is therefore a considerable extra burden to the structure, resulting in an increased cost for material, forms, and supports. This waste becomes greater with increased spans and under heavy loading, especially over a water surface where expensive means of form supports are generally required. Mr. Taft.

During the past years a number of flat-slab types of construction have been brought out, all generic of the first idea, the so-called mushroom system; some of them are nothing more nor less than a shallow-beam system masquerading under the name of flat slab. From reliable data furnished the writer, the thickness of the deck slab of these special types is so great as practically to counterbalance any material saving over a beam system, and it is an open question whether there is an actual cash saving in adopting such flat-slab systems.

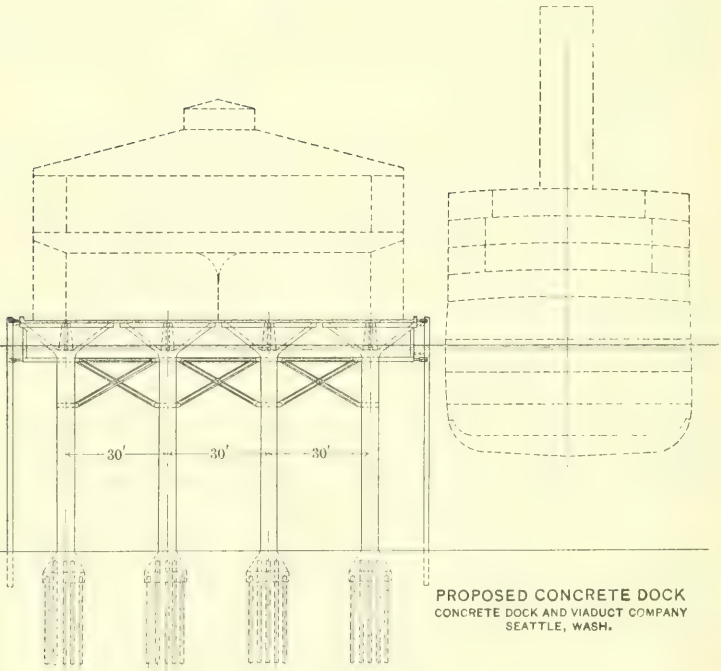
Even if more economical, are these various flat-slab systems suited to dock work and the heavy lateral thrust that the docks have to stand? If not, is it possible to produce a new genera of concrete construction, either of a beam, a flat slab, or other type that will stand in a class by itself and be suitable for dock work as well as for other heavy types of reinforced concrete construction? The writer's answer to the question is shown by Figs. 7, 8, and 9, of which only a brief description will be given at the present time. This system consists of large expanded hollow heads placed at the top of ordinary solid or hollow columns. The heads are of a conical or pyramidal shape, with a center post and diaphragms. Resting on the upper rim of the heads is the flat deck slab, sufficiently reinforced by non-trussed bars running diagonally, longitudinally, and crosswise, as may be necessary. The center post, the deck slab and the flaring sides of the heads form a perfect truss, integrated completely around the axis of the column. The heads should be poured some days in advance of the slab, the slab being poured after the heads have become well hardened. The necessity of binding the heads and the deck slab securely together will depend on the purpose of the structure, that is, whether it is to carry direct vertical loads only, or to absorb lateral shock in addition to a vertical load, as in dock work.

Mr. Taft.



PROPOSED CONCRETE VIADUCT
CONCRETE DOCK AND VIADUCT COMPANY
SEATTLE, WASH.

Fig. 7.



PROPOSED CONCRETE DOCK
CONCRETE DOCK AND VIADUCT COMPANY
SEATTLE, WASH.

Fig. 8.

Mr. Taft.

The heads may be likened to spread foundation work, made hollow and turned upside down, or the well-known household tin funnel resting on a firm foundation and supporting a slab or platform on its upper rim. The deck loads are supported by the expanded heads and transmitted through them to the columns and distributed on the piling or hard substratum by the enlarged base at the foot of each column.

This system does away with all the tension concrete below the neutral axis of a beam system. The flaring sides of the heads are in direct compression and shear. Thus all the concrete in the heads acts directly in taking up the stresses due to the superimposed load.

This system not only reduces to the absolute minimum the quantity of concrete needed, but also does away with trussed steel. This results in a structure far more economical than an out-and-out beam and slab system carrying heavy loads.

To absorb the lateral thrust on the dock, a suitable system of bracing of one type or another is provided, as shown. There is also a system of fender piles with their rebuffer springs, the lower spring supposedly absorbing the larger part of the lateral pounding and transmitting it directly to the bracing without any rocking of the heads.

Just a few words regarding the quantity of concrete in such a system as compared with that in a beam and slab type, as the cost of a structure depends to a large extent on the quantity of material that goes into it: A reliable estimate of the quantity of concrete in one of these special structures indicates a possible saving of more than 20% over a standard beam system. Hence, about the same saving in cost would be expected.

In order to obtain an unbiased opinion on this special type of construction, the writer engaged H. F. Tucker, Assoc. M. Am. Soc. C. E., a specialist in reinforced concrete, to investigate this design thoroughly in all its many and unusual phases.

Referring to Fig. 9: The structure is designed for a uniform live load of 1 000 lb. per sq. ft. over the whole panel as compared with 500 lb. per sq. ft. for the author's structure. A careful estimate will show that the quantity of concrete in this special structure for a 20 by 20-ft. panel, exclusive of the column part below the head, is practically 13 cu. yd. The quantity of concrete in Mr. Staniford's structure for the 20 by 20-ft., 10½-in. slab is the same. Inasmuch as the tentative design is for a direct vertical load of 1 000 lb. per sq. ft., perhaps it is not an equitable comparison; but, in a similar design for only 500 lb. per sq. ft., the saving in concrete would be sufficient to cover the cost of providing sufficient bracing against lateral forces. Thus this type of construction compares most favorably with the author's design. As the depth of the head is practically equal to the freeboard of New York City docks, by placing the expanded head on a cluster of piles, it would appear that such a semi-concrete dock could be built at the

Mr. Taft.

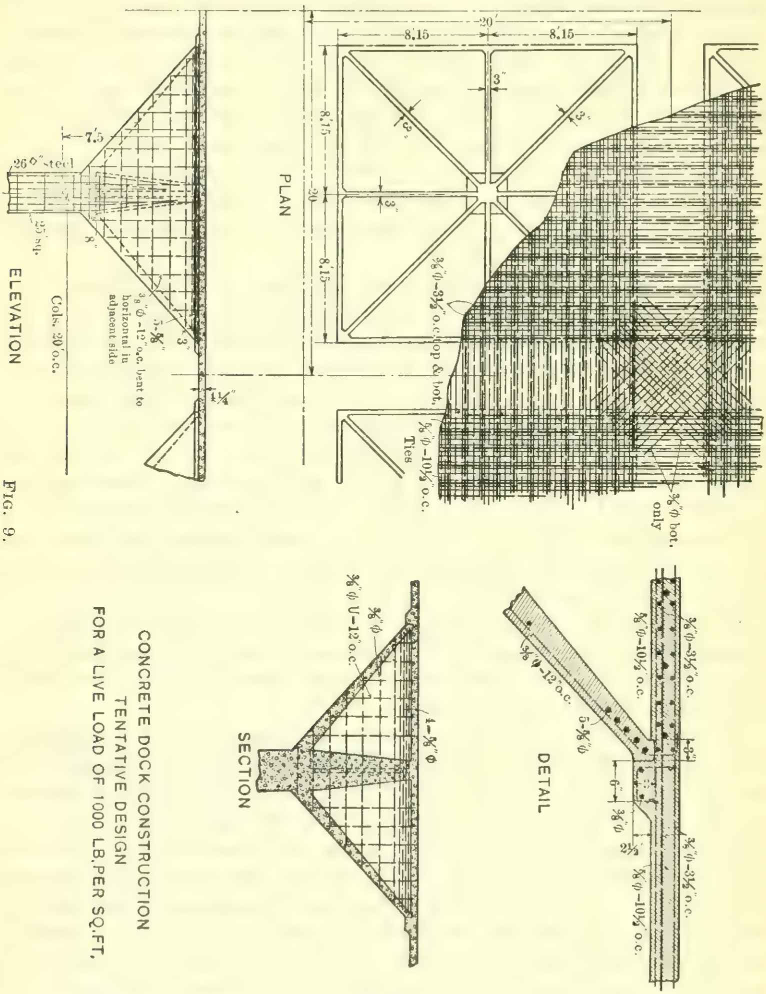


FIG. 9.

CONCRETE DOCK CONSTRUCTION
TENTATIVE DESIGN
FOR A LIVE LOAD OF 1000 LB. PER SQ. FT.

same, if not at a less, cost than Mr. Staniford's type, and would eliminate the repair work between the deck and high tide in his type of dock, which he states is necessary. With such a comparison as this, would it not seem that the author's remark about prohibitive first cost is open to discussion, and that a permanent full concrete dock will not be prohibitive in first cost if built on this special design? Mr. Taft.

From the prolonged study which the writer and Mr. Tucker have made of this new type of construction, they feel that the quantity of material required has been reduced to a minimum, without any reduction in strength, and that a dock having this type of deck construction will prove to be most economical in first cost, and still more economical in maintenance when compared with one of wood.

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PAPERS AND DISCUSSIONS

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PHYSICAL VALUATION OF RAILROADS.

Discussion.*

By Messrs. J. Shirley Eaton, C. P. Howard, M. H. Brinkley, Albin G. Nicolaysen, and F. A. Molitor.

J. Shirley Eaton, Esq. (by letter).—Mr. Wilgus' paper is comprehensive and critical, and is probably the most succinct statement of the problem which has been made. Its distinctive value lies in its emphasis on the indirect elements of cost of reproduction, which are the inseparable incidents of any actual work. Amateurish valuation fails at this point: It tends to limit its scope to the inventory of physical things at physical measurements at time of valuation, extending the parts inventoried at arbitrary unit prices. The practical engineer understands the necessity of large allowances for contingencies, for errors of judgment, and for changes of detail in the course of construction. Each section of road built involves its special risks and adjustment to local conditions. From the standpoint of personal experience the writer would reproduce a railroad property, carrying it through all the stages of an actual construction under usual conditions. Not only would he include supervision, accidents, taxes, and administrative expense, but he would make provision for the costs of capital that must be held in suspense during the period of construction, and also for the necessary working capital. Mr. Eaton.

In assigning the work of valuation by geographical divisions, under consulting expert supervision for right of way, signals, and special construction, the author keeps his controlling factors in co-ordination, and gives due weight to local conditions. In predicating an assumed interest rate of 6% on an allowance composed half of stock and half of bond financing, he ignores the fact that many railroads are financed on bond issues alone.

* Continued from August, 1913, *Proceedings*.

Mr. Eaton. A distinction between valuations according to the purpose which they are intended to serve, is unfortunate. A "valuation" should always be complete and the same thing, having reference to that entity which is defined by the operating income. The law is properly criticized in its provision for a valuation less depreciation. A railroad, as this paper so well emphasizes, is not an aggregate of parts, but an organism of parts, progressively integrated and evolved into a homogeneous whole to produce an operating income. The physical parts have two factors of efficiency which, as capital, must be maintained unimpaired, namely, what may be called the current efficiency and the life efficiency. Every year of use exhausts a year of the life efficiency, and so far reduces the capital value of the original plant. Income account, through which are made the adjustments to maintain capital unimpaired, must bear the charge of accumulating the offsetting reserves from which this reduction of life efficiencies is restored later. Otherwise, the net earnings are overstated to the extent that they have not made allowance for dissolution of the plant. In theory, a net earning figure can reproduce itself indefinitely out of the existing plant. A plant from which depreciation has been deducted will not permit of the indefinite reproduction of existing earnings, and a valuation based on original cost less depreciation, therefore, does not represent the necessary capital involved for the continuation of operating income.

The author touches lightly on the mooted question of including unearned increment in valuation, although this is the storm center about which most of the controversies will arise. In the same category with unearned increment are those values in the physical property representing donations by the community, state, or nation, and the reinvested surplus out of questionably excessive earnings of earlier years. Nor does he touch on another point sometimes urged—the practice of carrying the unearned increment through income account instead of through profit and loss, and thus establishing a rate of return that shall reflect back on the capitalization permitted, which practice would be distinctly wrong. We are at a time when principles of private property in a simple economic society are being complicated by the intrusion of vast values which are the direct result of social production. The analytic methods of latter-day bookkeeping are tending to distinguish these values from those created by individual enterprise and effort, and to relate them to the sources from which they spring. The problem of how to make this distinction and how far to carry it, becomes a critical and real issue with railroad property first, only because here are gathered, in orderly array, vast aggregates of property to which formulas are more easily applied than to the miscellaneous array of property held privately. We are not ready to believe

that the conditions of railroad investment are so different as to make them an exception in this particular, but the question that is raised first in this connection will doubtless be extended in time to include privately held properties as well as those devoted to public utility. Mr. Eaton.

One general criticism of this paper, which applies to all treatments of this subject, is the author's indisposition to strike at the social principles involved and his inclination to limit the discussion to terms and concrete phases. The law is not an illuminating guide. The principles of valuation are not yet stated or known, and while they will be evolved inductively in the concrete studies which the practical application of the law imposes, nevertheless, it would be advantageous, in discussing the matter, to have a leading thinker like Mr. Wilgus intimate the larger social consequences of the undertaking. With these wider aspects before us, in meeting the miscellaneous questions as they arise, there will be built up, not only a practical plan of valuing railroads, but a body of experience out of which will emerge a restatement and a more specific definition of property.

C. P. Howard, M. Am. Soc. C. E. (by letter).—In the text of the so-called "Federal Physical Valuation" law, the word "physical" occurs once in connection with classification of property. It also occurs once in a marginal subheading. The law, however, provides for a complete valuation, including "other values, and elements of value, if any," and the "present value" of "all lands, rights-of-way and terminals." Mr. Howard.

In this connection, the writer desires to call special attention to the subject of land values; to certain important elements which affect such values; to other elements of great importance which affect them from a railway standpoint; and, very briefly, to the question of whether these latter should be considered as "land" or "intangible" values.

A mere statement of facts as to the existence and importance of some of these elements might appear sufficient, and any argument on the subject as an attempt to demonstrate self-evident truths; nevertheless, in view of a recent Court decision, a thorough consideration of the subject would seem to be in order.

Suggested Definition of Value.—What is the value of a piece of property? The following definition is suggested: "The value or market value of a property is its greatest actual value for any lawful purpose for which it may be used and for which there is a demand."

A piece of ground may have no value for industrial or agricultural purposes, but it may have a high value as a residential site. Another tract may be valuable as a site for a wharf, railway terminal, or something else. Its highest value governs; or, if it has value for more than one purpose and can be used simultaneously for both, the sum of the values will govern— for instance, fertile farming land underlaid by a coal vein.

Mr. Howard. *Cost of Right of Way.*—Mr. Wilgus calls attention to the items of "severance and other damages, plottage, etc."

A narrow strip of land laid off across the country without regard to existing boundary lines cannot be purchased at the price obtaining for ordinary farm lands. As a general proposition nobody would sell such a strip, splitting his farm in two, for anything like the price per acre which would apply to the farm as a whole. Considered as an article of commerce it costs more to produce it. To the ordinary price for land must be added the depreciation in value of the remaining land, due to separation of parts and other damages. The Courts recognize this in provisions for damage to the residue. The law does not allow any general increase of land values to offset "damages to the residue"; if it did, the man with a farm near the railroad, but not touched by it, would receive the full benefit, and have an unfair advantage over his neighbor who would have such increase deducted from his land damages. An increase in price, therefore, is lawful, just and customary.

When a railroad is needed, and such a strip is judiciously located the demand for the property is imperative, even at such increased price.

Its increased value is due to its shape, position, continuity, etc. elements quite different and distinct from its original value for farming or other purposes, and having little relation thereto.

Continuity.—The continuity of a railway right of way is undoubtedly a most important element of its value. A right of way along a mountain stream might be extremely valuable for railway purposes if continuous; but if it is blocked by some impassable obstruction at one point, it would have no value whatever. This, of course, is self-evident.

Value for Railway Purposes.—Railroad companies have fought each other "tooth and toe-nail" for gaps and passes through the mountains and elsewhere. In these cases the value for a lawful purpose and the active demand for same are perfectly evident. Among a number of contests of this sort, which have come under the writer's observation, the following instance may be cited:

Two railroad companies located their lines through a gap in the mountains. A bought the right of way. B claimed prior location and sought to condemn. The lower Court decided for B, and testimony was taken as to the value of the land. An engineer for A, questioned as to its market value, placed it at $25 000, based on value to its owners for the purpose for which they proposed to use it, that is, for the construction of a railway tunnel. Its value for any other purpose would have been a mere trifle. The sequel is interesting. Road A, being deprived of its right of way, went ahead with the construction of a longer tunnel on another line a few hundred feet south of the main gap. Road B completed the tunnel through the main gap. The

Superior Court on appeal decided against Road B, and Road A then had two tunnels. Mr. Howard.

As a matter of fact, it is perfectly evident that the value of land for railroad purposes is a distinct and important element of value. One line may be worth as much or more than another line which cost considerably more to build, its greater value in excess of cost being altogether due to its more favorable location, that is, the greater value of its land for railway purposes. This does not necessarily imply a difference in engineering skill, the first line having first choice in the selection of its route.

Existing railroads in many parts of the country occupy natural or strategic routes which, from the shape of the land and the general configuration of its slopes, are especially adapted to railroad purposes. At present, these routes are of great value, and are likely to become more so in the future.

The importance of passes and defiles in the mountains is well known to engineers; for instance, the New River Gorge, occupied by the Chesapeake and Ohio Railway; the Ohio River below Pittsburgh; the Allegheny, Monongahela, and Youghiogheny Rivers at and above Pittsburgh; and the Susquehanna above and below Harrisburg.

Let any one spread out the sheets of the U. S. Topographical Survey from Pennsylvania to Georgia, note the railroads which have recently been built, and study the situation carefully. He will see how difficult, if not impossible, it will be to get another low-grade railroad line from the Ohio River to Chesapeake Bay, or to any point on the Atlantic Coast, below Norfolk, without using the tracks of an existing railroad. The Potomac, James, and Roanoke are the only rivers which cut through the Blue Ridge Mountains. On the route from Pittsburgh to the Potomac both banks of the Youghiogheny are occupied; this is also true of the Potomac from Piedmont to Cherry Run, near Hagerstown, Md. Between the Potomac and the Chesapeake and Ohio Railway, are a number of high ranges running northeast and southwest, and lapping past each other like interlocked fingers. From the Chesapeake and Ohio, on New River, southward to the Norfolk and Western Railroad, there are numerous ranges of hills and mountains; and from Roanoke south to Rabun Gap, Georgia, the eastern slope of the Blue Ridge falls off like the roof of a house, with the highest mountains of the Alleghanies to the west, and still farther west lie the Cumberland Mountains.

It is impossible to state how many other railroads would have been built from Pittsburgh east, if there had been a place to put them, or how many east and west lines south of the Potomac; one would have to be familiar with all the various surveys of proposed railroads. The writer knows of one company which attempted to build west, in the

Mr. Howard. territory between the Potomac and the Chesapeake and Ohio Railway; it built a short distance and stopped.

The value of ground for railway purposes, or its location value, is well illustrated in the case of terminals in a large city. If the business is sufficient to justify the construction into the city of a new line (B) at a cost of \$10 000 000, then, as a matter of fact, the value of the old line (A) entering the city from the same direction and giving the same facilities, would be not less than \$10 000 000, even though the cost of reconstructing it on its present location should be estimated at one-half or one-third that amount.

It may be assumed that the old line, having first choice of location, cost less as to physical features of construction, including grading, bridges, etc., that its land cost less, and that at present it would cost less, if valued on the basis of adjacent property without improvements. The new line, however, has to buy property with improvements; then tear them down, and build its own structures. Stated in another way, the value of an existing line is evidently not less than the cost of its reproduction on a new right of way, when sufficient demand exists to justify the construction of an additional line; and as no one will invest without expectation of increase, to this value should be added a reasonable percentage for profit.

When the business of the route will support only one road, any special value due to its advantageous location is not so apparent. But if the business is increasing toward the time when it may no longer be accommodated by the increased number of tracks of the existing road (and it is only a question of time when a second and more expensive line will be required), then the value of the location of the existing road, or of its lands, for railway purposes, may be said to be likewise increasing.

Credit for Location Value.—It has generally been conceded that the owner of property is entitled to its value for any lawful use, such as farming, building, etc. It is not the writer's purpose to suggest who should be credited with the special value of land for railroad purposes—the State or the railroad—but rather to emphasize the fact that this value exists.

How to Estimate the Value of a Location.—Railroad companies, if left to themselves, might settle the value of their lines, including that of location (or that of their lands for railway purposes), by the natural process of competition, provided they did not combine; but if the Government decides to make a complete valuation of railroads for purposes of rate-making, it must consider the various elements which would fix the value according to natural laws of supply and demand, such as the cost of construction, number of available routes, and number of roads, tracks, etc., necessary to handle the business.

Mr. Howard.

If it decides to give a railroad company the credit (or, in some cases, perhaps, the debit) of the value of its location, or the adaptability of its land for railroad purposes, how may such value be determined? This is a difficult problem, yet railroad companies have had to solve it in the past; and, if left to themselves, will have to do so in future. It takes investigation, time, and money. To consider it as an "intangible" rather than a land value makes the problem no easier, if an attempt is made to ascertain its amount in dollars and cents. It must be remembered also that railroad companies themselves have not asked for this investigation.

The process of determining the value of a location, as practised by railroad companies, is simple enough in a way; but it is expensive and tedious. A company desiring to build through a certain territory and finding the natural route occupied by another road, makes careful surveys and estimates of the cost of building an alternate line. If it costs too much, an endeavor is made to secure trackage rights over the existing line. If it is found necessary to build the new line, then other things being equal, the excess cost of the new line over the old, actual or computed, may be taken as the value of the location of the old line, or the excess value of its land for railway purposes.

"Location," "Land" or "Intangible" Values.—There are certain cases where the cost of reproduction on a new right of way would seem to be a logical method of determining the value of land for railway purposes—in other words, the cost of reproducing the right of way; there are other cases where this method might be used as a check or side light. It probably makes no difference whether it is considered as "physical," "tangible," or "intangible," provided all existing information is used and every effort made to determine its true or probable value.

Mr. Brinkley.

M. H. Brinkley, Assoc. M. Am. Soc. C. E. (by letter).—While the general principles enunciated by the author are interesting, and the paper is a valuable contribution on the subject of valuation, the writer desires to take issue with some of Mr. Wilgus' conclusions.

Since the paper was published, the decision of the U. S. Supreme Court has been made public, and its conclusions have been very far-reaching in regard to the value to be considered for rate-making purposes. It clearly sets forth that rates should be charged on reproduction value less depreciation, or what might be called depreciated reproduction value. A quotation in part is as follows: "When an estimate of value is made on the basis of reproduction new, the extent of existing depreciation should be shown and deducted." As the significance of the case was the question of rates, there is no doubt of the consequence of the decision that rates should be based on depreciated reproduction value.

In the following discussion depreciated reproduction value will be called present value.

Mr. Brinkley.

After a railway is built, renewals do not take place at once, but additions and betterments may be made, the cost of which should be charged to capital account. Starting with the property new, there will be a gradual depreciation, based on the rate of depreciation of the different elements of the property. When it is necessary to renew the items of shortest life, allowance must be made for the expense of replacements.

Assume that from the beginning of operation of the railway, the earnings have been sufficient to pay interest on the investment and create an accrued depreciation fund, which, at the end of each year, is equal to the depreciation below reproduction value. If, however, no fund has actually been created, then before renewals start, the net income is larger than in later years by an amount equal to the average annual renewals of the later period. Advantage may be taken of this by paying larger dividends to stockholders, or the amount may be placed in additions and betterments. The latter is frequently done, for often on railways recently built a large number of improvements take place. In either case, the stockholders gain, and there is what amounts to a repayment of capital invested.

For a property which has never made payments into a depreciation fund, the yearly replacements must come out of earnings. Assume that the railway is composed of a large number of elements of different life, such that after a certain age is reached, the present value remains constantly at the same percentage of reproduction value, due to the fact that replacements are the same in amount each year. This is not a special case, as a large amount of railway mileage approaches this condition very closely. If the property is allowed to earn interest on present value, and the cost of the annual replacement is provided for, the rates charged to the public will be the same as if a depreciation fund had been established at the beginning, being kept approximately equal to the total depreciation and earnings continually allowed on reproduction value. In this argument, it is assumed that the rate of interest on the depreciation fund is the same as that allowed on reproduction and present values. The proof of the above proposition is as follows:

Let i = rate of interest allowed on reproduction or present values;
a = rate of interest on depreciation fund;
R = reproduction value;
P = present value;
N = annuity required for contribution to a depreciation fund established at the birth of the property, which fund at the end of a certain period will remain equal to the depreciation below reproduction value;
D = value of the depreciation fund;
and, A = cost of annual replacements.

Mr. Brinkley.

Then in the case where earnings had always been allowed on reproduction value and a depreciation fund provided, which after a certain age remains equal to the total depreciation, interest on the reproduction value plus the amount of the annuity must be provided by net earnings, or $iR + N$. As the property is assumed to have reached an age when the annual replacements paid for out of the fund are constant, as well as the depreciation fund, it follows that $aD + N = A$, or $N = A - aD$. Substituting for N its value, the net earnings must amount to $iR + A - aD$. But $R - D = P$, and if $i = a$, the amount to be provided by net earnings becomes $iP + A$. This proves the proposition, as the same amount emerges, which it is contended should be allowed for net earnings where no depreciation fund has been provided. It seems to be clear from the foregoing that if earnings are allowed on the present value, together with a surplus for annual replacements, the property is on the same footing with one which has established a depreciation fund by annuities and is allowed earnings on reproduction value.

If no depreciation fund has been established, it should be assumed that the earnings, which should have contributed to such a fund, have been spent in extra dividends to stockholders or used in additions and betterments, in either of which cases the result is that of a repayment of capital. It is accomplished in the former case by direct repayment and in the latter by increasing the reproduction value of the property without any capital outlay. Besides, the apparent loss in value of the property is very much reduced on any railway more than a few years old by the unearned increment of right-of-way values. The term, right of way, as used, includes real estate and terminal lands. The market value of such land is usually more than the amount originally paid for it, and in the case of the earlier railways many times more. With the value of the right of way equal to 20% of the total value, it is easily apparent that, in the case of the earlier railways, the unearned increment of right-of-way values might amount to more than 15% of the value of the property. This, with the appreciation of grading, would be sufficient to take care of the difference between reproduction and present values. There may be some railways of light traffic, on which excess earnings in their early life and increase of right-of-way and terminal land values have not been sufficient to balance the depreciation. In such a case, the stockholders have simply made a poor investment.

If provision is made by the railway company for replacements by a replacement fund of such an amount that it will be just wiped out in the years of heaviest replacements, then it would be equitable to allow the company net earnings sufficient for interest on the present value plus interest on the amount of the fund plus an annuity for the replacement fund. The same result would be achieved by allowing

Mr. Brinkley. net earnings sufficient for interest on the present value, plus an annual payment into the replacement fund, no interest being allowed to accumulate in the replacement fund, being given to the stockholders instead for the use of their capital in the fund. As the sum of the present value and the amount of the fund will always approximate a constant value, the rates paid by the public should be the same general average through a group of years as if calculated on the basis of present value alone. Also, considering the fund as a part of the capital, no additions to capital account need be made for replacements as their cost will be taken out of the fund.

Depreciation is not a wastage of capital if its capital value is repaid, but as far as the property is concerned there is a diminution of value. If depreciation is a liability of the stockholders, earnings should only be allowed on the present value, for, if earnings are allowed on reproduction value, depreciation then becomes a liability of the rate-payers.

If earnings are allowed on reproduction value, and normal depreciation is treated as an element in the cost of operation that is covered by the rate, then, if no depreciation fund has been created, rates must be increased as depreciation takes place and replacements increase, since the reproduction value remains the same.

If there is no depreciation fund, and earnings are allowed on the reproduction value, then this becomes the selling value, as the latter is the capitalized value of the income. It has been agreed by the author, however, that the selling value or the capital invested by the purchaser should be based on the present value. It follows that earnings should be based on the present value instead of the reproduction value.

For property which has been allowed to deteriorate below the normal present value, it becomes a liability of the stockholders to place the structures in fair condition to the extent of the difference between the deteriorated value and the normal present value. In this case the stockholders should be penalized by a reduction of interest on investment sufficient to authorize this difference in values in a convenient length of time. During this time, the replacements necessary to bring the property up to normal condition, would be made. Earnings, insufficient in the past to take care of replacements, would be mitigating circumstances.

The decision of the U. S. Supreme Court in the "Minnesota Rate Case" also covers thoroughly the question of right-of-way values. A quotation in part is as follows:

"The company would certainly have no ground of complaint if it were allowed a value for these lands equal to the fair average market value of similar land in the vicinity, without additions by the use of multipliers, or otherwise, to cover hypothetical outlays. The

allowances made for a conjectural cost of acquisition and consequential damages must be disapproved; and in this view we also think it was an error to add to the amount taken as the present value of the lands the further sums calculated on that value, which were embraced in the items of 'engineering, superintendence, legal expenses,' 'contingencies,' and 'interest during construction'." Mr. Brinkley.

This decision seems to be fair, both to the railways and to the rate-payers. The right-of-way values for the older railways will be much enhanced over the original cost, and it is not probable that the newer lines will suffer any hardship. The normal increase in land values, consisting of yards, terminals, and right of way, after a railway is built, is usually sufficient to provide for the extra cost of right of way over the market value at the time of construction. Some actual data, comparing original cost with present market value for land values of a complete railway system, would be interesting. However, it should be unnecessary to consider this question if we neglect original cost and consider only reproduction value. The present values of adjoining land have been created on account of the existence of the railway itself, and if the railway was to be built at the present time, the present land values would certainly not obtain. The only exception would be in case another railway existed in the same vicinity, which fact would also have influence in creating land values; but in any town certain land increases in value when another railway is built. Nothing can be known of what the land values would be if the railway did not exist. It seems to be expedient as well as good judgment under the circumstances to allow full market value and no more. The only other alternative is to give some consideration to original cost in the fixing of rates. A percentage for contingencies and interest during construction is evidently superfluous as it has nothing to do with the present market value of the land.

The writer agrees that the ordinary method of calculating interest during construction is unfair to the company. By this method one-half of the total interest allowance for the time of construction is taken; two-thirds or three-fourths would probably be more nearly correct. If this is done, however, care should be taken that a too liberal allowance for time of construction is not made.

The author's views on depreciation are illuminating, especially on the subject of rails. In addition, it would be well to state that rail breakage should also be considered, and available statistics on this subject for each railway studied.

It seems to the writer that depreciation in general should be handled only by an expert. The chiefs of ordinary field parties have not the experience and ability to judge accurately of the condition of structures, and the variations in their opinions are too great. In order to obtain the depreciated value, all structures should be examined

Mr. Brinkley. by an expert and their condition noted. When the inspection is made, he should have the age of the structure, if such information is in existence. The percentage depreciation can be more intelligently noted if the age is known.

In view of this discussion, conclusions indicate that the recent Supreme Court decision in the Minnesota Rate Case, in regard to the basis for the valuation of railroads, is fair both to the railway companies and to the rate-payers. From the arguments and facts it does not seem possible that any other basis for rates than that of present value with right of way included at market value of adjoining lands, could be made without gross injustice.

Mr. Nicolaysen. ALBIN G. NICOLAYSEN, ASSOC. M. AM. SOC. C. E. (by letter).—The valuation of common carriers to be made by the Interstate Commerce Commission promises to be of such great importance both to the public and the railroads, and opinions as to the proper principles to be followed vary so greatly, that Mr. Wilgus' paper is most timely.

The author has given a clear presentation of his views, and the force of many of the arguments is admitted, but to the writer it seems that the railroads have generally received a little more than the benefit of the doubt. Thus it seems proper enough that some allowance should be made for solidification of embankments, but to advocate that such allowance shall equal the estimated cost of compacting the embankment as an earthern dam would be compacted at the time of its construction, does seem to be rather arbitrary. It is also certain that the surfaces of cuts become seasoned in time, so that the trouble from slides and filling of ditches is materially less in an old than in a new cut, and that the appreciation of the cuts may bear a close relation to the cost of maintaining the slopes from the time of construction until they become fairly stable; but the appreciation of the cuts is somewhat less, and not equal to the cost of maintaining them during the period of settlement, as some cleaning of ditches will always be required. However, where the difference between the two values is small, it seems to the writer to be reasonable and fair to give the railroads the benefit of the doubt, taking into account the fact that, in some cases, valuation for rate-making purposes may work hardship to innocent investors. The author, however, appears to claim that even an additional allowance, equal to the cost of establishing vegetation by artificial means, should be made where the cuts have become covered with vegetation which protects the surface. This claim seems clearly against the fundamental principle that physical value is determined as the cost of reproducing the property in its present condition, under the assumption that the natural topographical conditions along the line are as they were at the time when the road was built, while, in other respects, the conditions are taken as they exist to-day; under this theory Nature

may logically be assumed to re-establish vegetation in places, where it has established such vegetation in the past. Mr. Nicolaysen.

It appears to the writer that most appraisers would make some allowance in the physical value for interest during construction, cost of promotion, banker's commission on securities (but not discount on bonds), contingencies, and similar items, so that the difference of opinion regarding these items would be confined mostly to the question of the proper allowance to make for each. This the writer does not consider himself qualified to discuss further than to state that it would seem reasonable to assume that an examination of the books of recently built roads would disclose data from which these items could be estimated quite closely.

There remains one fundamental question on which the writer differs absolutely with the author, namely, whether the proper physical value for rate-making purposes should be determined as the cost of reproduction new, or whether a deduction should be made from this value to cover depreciation.

As long as it is agreed that depreciation shall be included in maintenance, and that the renewals shall be charged as operating expenses, it seems clear that the physical value for rate-making purposes is the cost of reproduction new, less depreciation. To illustrate this contention it may be assumed that a certain road was built as a unit. When new, the physical value equalled the cost of reproduction new, since no depreciation had occurred. After the road had been in service for one year, a certain depreciation took place, but this depreciation was a part of the operating expenses for that year, and may be assumed to have been placed in a special depreciation fund. If this has been done regularly, there will exist at the present time a fund made up of yearly appropriations equal to the depreciation for each year less the cost of renewals made in the period considered, and this fund should equal the depreciation on the road as it exists to-day. The road under consideration is clearly entitled to a return on the cost of reproduction new without any deduction for depreciation, but the depreciation fund may logically be assumed to be invested in such a way as to earn interest on itself, and the net earnings from operation need only be large enough to provide for a return on intangible values, if any, and on the cost of reproduction new, less depreciation.

It is granted that such a fund is rarely established, but this does not alter the case; it simply means that the stockholders have drawn out of the road more than was really available for dividends, and have thus reduced their investments in the property by an amount equal to the depreciation. As long as the property is kept in good condition, no objection can be made to the withdrawal of money which, in a sense, belongs in a depreciation fund, because the average condition on a well-maintained road of any magnitude differs but little from

Mr. Nicolaysen. year to year, and it will never be necessary, or even possible, to renew all of the property during one year.

If maintenance expenses are considered in connection with the return on physical value, it will be still clearer that depreciation should be subtracted from the cost of reproduction new, in order to determine the physical value on which a return may be expected. If this is not done, then two roads, A and B, for which the cost of reproduction is identical, will be entitled to the same return on their physical values, although A may be a fairly new road and in excellent condition, while B may be old and run down. Under such conditions the maintenance expenses, and, for that matter, the operating expenses too, would be far heavier on B than on A, and, as the roads are entitled to earn maintenance and operating expenses in addition to a return on the physical value, the result would be that the poor road, B, would be entitled to far larger earnings than the good road, A, which shows clearly enough that something is wrong with the basic assumptions. In fact, as the writer sees it, there is no doubt but that the physical value should be determined as the cost of reproduction new, less depreciation.

In connection with the question of depreciation, it would seem that average depreciation, rather than actual depreciation, should be used in the majority of cases. If an attempt was made to base the value for rate-making purposes partly on the actual depreciated value of the physical property, it would mean that the task of revising the valuation in order to keep it up to date would be almost impossible on account of the multitude of items involved. In addition, the writer believes that the result obtained by assuming that, say, all the untreated pine ties on a fairly large road had a present value equal to 50% of the value new, would be more nearly correct than that arising from an attempt to estimate the depreciation of each individual tie, although a still closer value might be obtained by estimating the average depreciation, bearing in mind that the normal depreciation would be 50% and the minimum and maximum depreciation, say, respectively, 35 and 65 per cent.

If average depreciation instead of actual depreciation was used to determine the physical value, the result would be a tendency toward stability in rates, field and office work would be greatly reduced, and the task of keeping the valuation up to date would be made practical.

It is admitted, however, that the actual depreciation of buildings and structures should be determined, not only because it is required by law, but also because it will furnish a guide in establishing average depreciation of different classes of structures and in analyzing maintenance expenses, the writer's belief being that average maintenance expenses must be ascertained as a step necessary to the determination of intangible values, if any.

Mr. Nicolaysen.

As, theoretically, abandoned property must be paid for out of the depreciation fund, it is obvious that such property as a spur to a mine which has been worked out, should only be given a nominal value. The same would necessarily apply to stretches of roads having such curvatures and grades as to make it impossible to operate trains economically over them under present conditions, to bridges which are too light to carry present rolling stock, etc. This, however, should be definitely settled and understood, else the natural result would be a postponement of a very large part of desirable improvement work along these lines, pending the completion of the valuation.

To the writer it seems that the value for taxation purposes may differ from that for rate-making purposes, but he is not certain that it would be impossible to distribute the several items of value between physical and intangible values in a way that is logical, and, at the same time, leaves the physical value the same no matter for what purpose it is intended. If it were possible, this plan would be highly desirable as tending to give the valuations proper standing with the general public. It requires, however, that the method to be used in estimating the intangible values be determined, and it is greatly to be hoped that some member of the Society will present a paper dealing with this subject.

Mr. Molitor.

F. A. Molitor, M. Am. Soc. C. E. (by letter).—The thorough and masterly manner in which Mr. Wilgus has covered the subject of the physical valuation of railways has left little room for further discussion. As the writer's professional experience, however, has been confined solely to the building of railroads, a few points which occurred to him in reading this valuable contribution on the pressing subject now before the Interstate Commerce Commission and the railways may be of interest. It should be stated, however, that the writer's experience has been in the commercial or practical field, and not in the political or academic work of valuation for taxation or rate-making purposes; therefore, his views on the general subject may be biased.

Although the purpose of the Federal Act for the physical valuation of railroads is not stated specifically in that Act or elsewhere, nevertheless, it appears to be for one or both of the following purposes: (1) For rate-making or regulation purposes; (2) to ascertain the value of the railroad properties with a view of determining their present physical appraisement for the ultimate purpose of Government ownership.

If either of these views is true, then the "original cost to date" is a mere bookkeeping task with the evident purpose of checking the results obtained by the engineering method of "cost of reproduction new" and "cost of reproduction less depreciation." The "sale method" may be dismissed from consideration, because, as Mr. Wilgus states, it can

Mr. Molitor. be used for taxation purposes only and hence is a State and hardly a Federal question.

Mr. Wilgus has stated the difficulties to be encountered in obtaining the "original cost to date," and an accountant or engineer may well shudder at the task of ascertaining in only the most general way the original cost of some of the earlier railroads, many of which have been rebuilt on entirely different alignment and right of way, the original roadbed having been obliterated by the elements and become a part of the landscape and topography. What possible value can such approximation of the original cost of a railroad, with additions and betterments and improvements added to date, be to the Federal Government? Or what standing will it have in Court? In fact, to what can an engineer consistently testify in the "original cost to date" except only what the books of the railroad company show?

It seems to the writer, therefore, that the only admissible method of valuation is the "cost of reproduction new" or "less depreciation," and he agrees with Mr. Wilgus' theory that the proper valuation for rate-making and regulation purposes is the cost of reproduction new, the depreciation, if any, being taken care of by the owners and stockholders as a liability. On the other hand, if the valuation is for the purpose of taking over and purchasing the railroad, then the depreciation should be considered only to the extent required in each railroad under consideration. It is at this point that the experienced railroad engineer may use his judgment. The writer is acquainted with many roads which are maintained in a first-class manner and would not in all fairness have any deduction for depreciation, because their general condition for the purpose of the public is as good as, if not better than, when it was new, as viewed and appraised in a broad and equitable light. Speaking academically, it is admitted, however, that each and every tie, panel, or track, or other detail of construction, is not new, and, therefore, from a percentage standpoint, is not "100 per cent. new." It is here that the fallacies of theoretical tables, based on the life of a construction detail or unit, and purporting to give its money value for each year of its life, are evident when the railroad as a whole, or as an operating plant for the public benefit, is being considered.

Another railroad which by inspection shows a physical depreciation to the extent that repairs of roadbed, bridges, and buildings are required, may well have a "less depreciation" deducted from its reproduction cost to the extent that the engineer may estimate, not, however, by counting the bad ties, but by estimating carefully what is required to place the road in proper condition in order to handle its particular traffic economically, and here it must be remembered that the traffic of the Pennsylvania Railroad requires a higher standard of roadbed efficiency than a short line in an outlying district with a light traffic density. Is this not an example of one of the "elements" entering into

railroad valuation in respect to the "less depreciation" item? And is it not the point of view to be taken by the valuation engineer that he must apply different standards to different railroads? The writer can well imagine the inexperienced man acquainted only with the maintenance-of-way standards of the Pennsylvania Railroad, or other Eastern railway, being detailed to value some Southwestern line. Would he not unconsciously estimate his "depreciation" on an Eastern standard and thereby injure the Southwestern stockholders? Mr. Molitor.

The writer has discussed the depreciation method because, since Mr. Wilgus' paper was published, the U. S. Supreme Court has ruled, in the Minnesota cases, that it must be considered, and although the writer has been of the opinion that it should rule only in roads under bad repair, we are now confronted with it in the valuation of the best roads, and it seems that, in considering depreciation broadly and having always in mind the traffic carried by each, and, in so doing, particularly avoiding formulas, we bring ourselves under the Supreme Court's decision.

Passing to the details of cost of "reproduction new," which must be first determined, regardless of depreciation, it seems to the writer that, in a general way, such cost can be estimated. It will be closer, perhaps, than an estimate of construction cost based on a careful final location, but, nevertheless, it is an estimate which, as far as graduation and masonry are concerned, is not nearly as close as the "final" estimate of the actually constructed roadbed. The masonry cannot always be reached to be measured. The excavations for foundations and classes of material thus encountered cannot be seen, and many like quantities of construction cannot be determined at all in the absence of plans and actual records of construction. On the more recently built railroads these may be found, but, to the writer's knowledge, no such records exist on many miles of lines, the construction staff having been dispensed with before the construction facts were recorded.

Sometimes the classification and overhaul of graduation quantities can only be estimated in the crudest possible manner. The fact that cuts are many years old prevents the most experienced eye from judging the original classification. Loose débris has slid down, covering the original roadbed walls, or weather has changed the character or classification of the visible material, giving hardly a hint of the classification of graduation originally moved, and no hint at all as to the quantities of classified material. In respect to overhaul, the original method of handling the work should be known. What sort of plant was used, whether scrapers, wagons, or cars? Here, again, the engineer, inexperienced with the locality to which he is detailed, may fall into error by assuming the use of a grading plant inconsistent with, and expensive for, the original work.

Mr. Molitor. The writer has mentioned some of the units of construction which cannot merely be inventoried or measured, but must be estimated, and, in consequence of which, the personal equation will enter into the valuation to a large degree, requiring eternal vigilance and care on the part of the valuation engineers, in order that their estimates may not be overthrown by the Courts on the testimony of the experienced and expert engineers of the railroad companies.

Referring to some units of construction which can be measured, engineers are sometimes confronted with the unit prices to be placed on them. Land values are the most important of these, and the writer is in agreement with Mr. Wilgus' expressions in respect to using a stated multiplier against the normal market value to determine generally the cost to the railroads, which is known to be in excess of other land purchases; he is compelled, however, to change the method, but not his original opinion, by the Supreme Court's ruling in the Minnesota Rate Case, where it decided against the use of a formula or factor for determining the cost of lands. This decision leaves only the alternative of using the normal present market value, but if abundant proof is offered of the actual amounts paid in good faith for land by the railroads, the writer cannot but believe that such costs of land will be admitted.

"Engineering," in the writer's opinion, has generally been estimated too low, and as far as his experience shows, has been varied from 5 to 10% of the cost of the railroad proper, depending on the locality and topography, as well as the speed at which construction progressed. In the case of a physical valuation, the construction must necessarily be assumed to have continued without interruption due to lack of funds or other causes, otherwise a wide door is opened for varied and excessive engineering expenses. It seems equitable, however, to make due allowance for such delays if they occurred during the construction of a particular railroad.

"Contingencies" is an item which, as Mr. Wilgus suggests, must be given due consideration, and is dependent on the individual cases presented in the railroad valuation.

Such minor items as insurance, stationery and printing, can be taken care of by a valuation engineer in no better manner than that suggested by Mr. Wilgus, but "law expenses" is an item that cannot readily be estimated by comparison with the like expenses of other railroads, because these expenses vary with each railroad and with the necessary legal work that was or should be performed in connection with railroad construction. As a general thing, the writer is of the opinion that law expenses have not heretofore been estimated as liberally as the facts and known expenses seem to warrant. Some railroads, through the selection of a contested route, or through contractors' difficulties, have experienced heavy charges for legal services during con-

struction. When a railroad is valued for the cost of reproduction new, is it to be assumed that no legal difficulties of this nature had been encountered? If so, a just and equitable valuation for this item has not been made. Mr. Molitor.

"Interest and Commissions," which cover the interest on the money invested in the railroad property presumably until such time as the railroad is completed, in operation, and becomes self-sustaining, and bankers' and underwriters' commissions, etc., are items susceptible of division of opinion and many interpretations, when placing a valuation on railroad property.

In the writer's opinion, a discount on bonds, as near as it may be determined by the probable credit of the railroad being valued, should unquestionably be allowed for, as it is part of the investing public's risk assumed in purchasing the securities of a new company, and the interest on which, therefore, should be paid for by the shipping public in the shape of the rates based on the total valuation of the railroad property, which should thus include the discount on the bonds. On one hand we have a small road with poor credit, the original construction bonds of which sold, say, at 60%, while on the other hand there is a subsidiary line of the Pennsylvania Railroad, for instance, the bonds of which, issued for construction purposes, would probably bring par to the investing public. In the consideration of the commissions and discount item in the valuation of these two extremes, should not this be taken into consideration to the extent of allowing no discount in the case of the Pennsylvania Railroad and 40% for discount to be added to the valuation to cover the legitimate risk taken by the investor in the small railroad company's bonds. The public thereby will pay a very small fraction of the interest on the 40% increase in valuation, in the shape of railroad rates. The only alternative would be that the public guarantee the interest on the bonds issued by the smaller company, so that by such additional credit they would bring par and a price equal to those issued by the larger railroad with its good credit.

The interest during construction, of course, is more readily obtainable by multiplying the estimated period of construction by the prevailing interest rate and dividing by the average period of time in which all the money was used, which, for practical purposes, has been taken as two, on the theory that the money expended during construction has been regularly distributed over that period, so that the average interest is one-half of the total amount. It is quite possible, on the other hand, that the money expended during construction has not been so evenly distributed as to permit of this course.

A case is within the writer's experience where the graduation was comparatively light, heavy expenditures were made for right of way, and the rails and fastenings were shipped in the early stage of construction, with sight drafts against delivery, so that something like

Mr. Molitor. 75 or 80% of the cost of construction was expended in the early months. The remainder, consisting of bridges and buildings, was built after the track was laid, resulting in the fact that 25% of the payments were not actually made until 18 months after 75% of the expenditures were made.

It is believed, therefore, that there is a wide latitude in the consideration of the "interest and commission item" in which errors and omissions may enter, to the manifest injustice of the investing public, on the one hand, and the shippers, on the other, if rate-making and regulation is based on the valuation. The writer is aware that some authorities have questioned the allowance of interest and commissions in valuation at all. To those he would suggest that, in the establishment of unit prices for contract work of any character or in any locality, there is contained this very item which is a universal trade condition and must be recognized. The contractor is obliged to borrow money from his bank to carry on his contract work, as his monthly estimates are admittedly not sufficient to carry his investment for plant and like purposes during its earlier stages. He pays the highest rate of interest, and he is reimbursed for these interest payments in the shape of a percentage added in his unit prices. In many cases the contractor is obliged to pay commissions, and this is also reflected or added in his bid of unit prices made to the railroad company. Therefore, if the railroad company reimburses the contractor for interest and commissions, although they are hidden in the unit prices, why should not the railroad have added to its cost in the valuation of its property by the authorities the item of "interest and commission" as a transaction between the railroad and its banker instead of a transaction between the railroad company's contractor and his banker?

The writer is pointing out some of the items that have come under his experience in railroad construction, and have been practical ones, with the view of promoting further discussion on Mr. Wilgus' paper from those members of the Society who have had charge of or have been connected with State railroad valuation in the past, so that a broad light may be thrown on the subject for the benefit of those who are charged with the Federal valuation of railroad properties.

In the valuation of equipment, Mr. Wilgus suggests that each unit need not be viewed personally by the expert appraiser. Nevertheless, it would appear advisable for the appraiser to inspect as many of the units of equipment as it is physically possible for him to do.

The writer's theory is that equipment, motive power especially, is subject to heavy wear and depreciation not always in the ratio of its age, because one locomotive or car of an equal age and original construction may have performed a greater mileage, or may not have been maintained as well as another, and though he believes that depreciation of the roadbed and structures must be regarded in the gen-

Mr. Molitor.

eral way as a single proposition, he feels that the equipment can, by actual inventory, be valued with the depreciation deducted and obtained in a careful and more exact manner. At the same time, the general overhauling and repairs made to equipment should be given the most careful consideration. Though the life of an engine may be taken at a given number of years, nevertheless, this life may be lengthened by systematic and careful general repairs and overhauling, which, in the case of many railroads, has been done. The past history of equipment is that it becomes obsolete rather than worn out. Its physical life is longer than its economic life, and it is not at all improbable that the latter should be taken into consideration in the value of equipment. That is to say, the unit value of a car of 100 000 lb. capacity is greater than one of 40 000 lb. capacity because of the greater operating efficiency of the former.

The writer is in the heartiest accord with Mr. Wilgus in giving due consideration and valuation to the preliminary organization expenses which are necessary incidents to the construction of any railroad. From the writer's knowledge, there have been instances in which these preliminary organization expenses have legitimately run into an amount equal to 20% of the cost of construction, and he believes that where a railroad company can show proof that such preliminary expenses have existed, they should be allowed in the valuation.

In conclusion, the writer recognizes the legal limitations within which much of the physical valuation of railroads has heretofore been undertaken by several of the States. He believes that though much of the information gained will be of value in the Federal valuation, nevertheless, there are many additional items which may well be taken into consideration by the Interstate Commerce Commission. He refers more particularly to the so-called intangible values. Some of the values that have been called intangible are not, in his opinion, at all intangible, and he will close by mentioning one very tangible item of the value of a railroad; with the hope of adding to the discussion further remarks on the subject.

The profile of a railroad has a tangible value and, therefore, should be considered in the physical valuation of any railroad property.

The economy of the operation of a railroad plant depends on a great many items, the principal ones being fuel, labor, and the profile. Labor rates are becoming practically uniform throughout the country, but the cost of fuel varies considerably. No item entering into the cost of railroad operation has a greater bearing on it than the profile, and, therefore, why should not the railroad, which, by advantages of location or by the efficiency shown in the location surveys in obtaining a lower grade line than another railroad, have this advantage expressed in the valuation?

Mr. Molitor.

The writer has knowledge of two railroads connecting two industrial centers. One of these has a grade line so much lower than the other that the "movement expenses" or cost of conducting transportation is not more than one-half that of the other road, not so wisely or fortunately situated. Should not the road of the lower gradient be given consideration in the valuation over the road of heavier grades? If valued for commercial purposes, the low-grade line would assuredly be valued higher than the railroad of a higher grade, because its net earning capacity is greater.

As the profile of the road is a physical feature, it would seem that a valuation could be placed thereon. The writer is not prepared to say at this time just how, but that some equitable basis could be arrived at for determining the profile value of a railroad is quite certain, and it is hoped that this subject at least will bring forth an answer from Mr. Wilgus.

The physical valuation of railroads now being undertaken by the Federal Government affords a great field for engineers in general, and for members of the American Society of Civil Engineers in particular, and it behooves them to study the problem carefully with the view of obtaining uniform methods and equitable results, and for such study no better text has been offered than the paper by Mr. Wilgus.

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PAPERS AND DISCUSSIONS

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ROAD CONSTRUCTION AND MAINTENANCE.
An Informal Discussion.*

By Messrs. J. A. Johnston, A. H. Blanchard, Sanford E. Thompson, E. H. Thomes, Philip P. Sharples, L. P. Sibley, Samuel Whinery, Harold Parker, William M. Kinney, James Owen, Nelson P. Lewis, L. L. Tribus, W. W. Crosby, George W. Tillson, William H. Connell, H. W. Durham, Frederick Wilcock, Jean de Pulligny, Bertram Brewer, Amos Schaeffer, J. W. Howard, C. E. Carter, F. O. Whitney, Francis P. Smith, H. B. Drowne, James L. Gaynor, H. C. Poore, W. S. Godwin, W. H. Kershaw, W. H. Fulweiler, and Prevost Hubbard.

CEMENT-CONCRETE PAVEMENTS.

J. A. Johnston, M. Am. Soc. C. E.—Great care is requisite in order to obtain good results in concrete pavements. In discussing the value of such pavements, there is, of course, some question as to the kind and amount of traffic they will stand. In Massachusetts, in 1906, a concrete surface was laid on a section of State highway in the Town of Spencer, and stood the traffic remarkably well. The principal objection was that it was rather hard for the feet of the country-bred horses, which, if allowed to select the traveled way, would turn out on the earth shoulders. A bituminous surface remedied this condition, and at present the road is giving excellent service. The section mentioned was put down by the grouting method, known as the Hassam process. On investigation it was found that the grout had penetrated, not only 6 in. of broken stone, but an additional 2 in. of gravel sub-surface. Very little trouble was experienced from disintergration of the concrete surface; it was confined principally to the area adjacent to the expansion joints. Mr. Johnston.

* At meetings held January 17th and 18th, 1913.

Mr. Johnston.

Since that time some roads have been built by mixing the concrete before placing. Care had to be taken to have the batch properly tempered, particularly in building on a grade. If too wet, the mortar had a tendency to creep and form waves on the surface, and, of course, a dry mixture was not readily flushed, hence it was difficult to get a good smooth surface. The concrete was placed in a single layer, and as near a mosaic surface as possible was desired, in order to permit the bituminous material to bond properly. To obtain that result various methods were tried. After placing the concrete, dry stone was spread over it, and tamped lightly. This worked well, but required considerable skill on the part of the men who were spreading the broken stone. The experiment of allowing the concrete to set for 24 hours, and then brushing it off with a steel broom, gave, perhaps, the most satisfactory results.

There is a tendency to use too lean a mixture for concrete road surfaces. Many engineers have advocated a 1:3:6 mixture, but that is not rich enough, for concrete exposed to the traction of wheels and blows from horses' hoofs must be very tough to resist abrasion. Added strength cannot be gained by reducing the percentage of stone aggregate, that is, assuming 2 parts of sand to be the correct quantity to be used with 1 part of cement. Such a mortar will fill the voids in 4 parts of stone, and no added strength is gained by reducing the stone aggregate to 3 parts. Too small a proportion of stone means a large percentage of mortar, thus giving a smooth surface, which would be slippery and not desirable.

The concrete pavement has the advantage of being not only a surface, but also a foundation. Though, of course, there may be conditions where some treatment of the sub-surface will be needed, with a uniform soil, in which the frost action is about the same in all parts, there is very little difficulty. If, however, the soil is varied, so that the frost will affect one portion of the road more than another, the concrete will crack. It is an unusual condition where such cracks are serious enough to disintergrate the concrete, and any ordinary cracking is not material. This is particularly true where concrete is coated with a bituminous material, as the cracks are then sealed over and give no trouble. With concrete, as with all other smooth paving, the surface is rather slippery, necessitating care in designing the maximum grades and the camber of the road.

A light bituminous top on a cement-concrete base solves many road problems. It is reported that there is much difficulty in making the bituminous material stick to the concrete. In Massachusetts success has been obtained by the following method: The concrete surface is swept as clean as possible, then sprinkled with water, and while still wet covered with Tarvia A, heated to 200° Fahr. and applied at a

Mr. Johnston.

pressure of not less than 70 lb. per sq. in., and at the rate of ¼ gal. per sq. yd. of surface. This is then covered with clean stone screenings (not exceeding ½ in. in diameter and from which the flour has been removed) spread at the rate of 0.015 tons per sq. yd. of surface. This is again watered, and while still wet a second ¼-gal. coating of tar is applied in the same manner as before, but covered with clean, gravelly sand, using 0.015 cu. yd. per sq. yd. of surface.

The speaker is aware that the application of tar on a wet surface is contrary to existing theories, but it has worked satisfactorily. This road, treated in August, 1910, has cost to date, $15 for total repairs on more than 4 000 lin. ft. of 15-ft. surface, and it has taken only 30 gal. of tar to replace such small places as have scaled off. The speaker believes the successful adhesion of the tar to the concrete is due to the wet surface of the latter and the high pressure used in spraying the tar on the road.

Mr. Blanchard.

A. H. Blanchard, M. Am. Soc. C. E.—Although cement-concrete pavements have been used in the United States since 1893, various details of construction and maintenance are as yet in an experimental stage. Many miles of cement-concrete pavements have been examined by the speaker, and the only ones which have been observed to be free from cracks are those which have been carefully constructed by the mixing method, and built on a well-drained, thoroughly compacted foundation, with adequate transverse expansion-contraction joints. Such joints are necessary, if successful results are to be expected, and both longitudinal joints along the curbs and transverse joints should be provided. If there are no expansion-contraction joints, the tensile strength of the concrete will probably be exceeded when the concrete contracts, and the pavement therefore will crack; when it expands, it will tend to bulge, and if the expansion produces forces which are in excess of the compressive strength of the concrete, the latter will crush at the cracks. It is obvious that the edges of the joints should be protected from the abrasive action of traffic, and it is likewise apparent that the joints should be filled with a material which will provide for movement between the joints as the pavement expands and contracts.

The maintenance of cement-concrete pavements is difficult, as it is necessary to keep traffic off the freshly laid patches. It would seem advisable to use a bituminous concrete for patching, and the bituminous cement should be of such a character that the bituminous concrete will be stable after thorough compression by tamping or otherwise. Naturally, a cement-concrete pavement repaired in this manner will not be pleasing from an esthetic standpoint. However, this point is not one of weight, as in all probability a large percentage of cement-concrete pavements constructed in the future will be finished with a bituminous surface.

Mr. Thompson.

SANFORD E. THOMPSON, M. AM. SOC. C. E.—One of the problems to be considered in the construction of concrete pavements is that of expansion and contraction due to changes in temperature. Contraction caused by the lowering of the temperature produces cracks, not only in concrete which is not reinforced, but also in brickwork or stonework. In the latter, however, the cracks are not apt to be so noticeable, because they follow the line of the joints.

Although it is possible to reinforce concrete pavements with steel so that the size of the cracks is inappreciable, the introduction of steel in sufficient quantity for this purpose is somewhat questionable from the standpoint of cost, and the problem, therefore, resolves itself generally into the location of the cracks where they are wanted, so that they will have smooth joints instead of rough, irregular lines.

Longitudinal joints through the middle of the pavement should be avoided if possible. Sometimes, it is advisable to make a longitudinal joint on each side of the pavement next to the curb. The spacing of joints across the pavement depends on climatic conditions and the extremes of temperature that will occur in the given locality. A spacing of from 20 to 30 ft. is common practice in first-class construction. If the concrete is laid in cold weather, at a temperature not very much above freezing, its tendency to contract is less, and the cracks will be apt to occur at a greater distance apart. In some cases, this fact may be taken into account in locating the cross-joints.

It is possible to calculate quite closely the actual amount of contraction which will take place during a falling temperature, and to determine the approximate size of crack that is likely to open. The coefficient of expansion of concrete is approximately 0.0000055; that is, for every degree of fall in temperature, the concrete contracts in this ratio. Suppose, for example, a section of concrete is 50 ft. long, and that it is free to expand and contract, the actual contraction caused by a fall in temperature of 40° Fahr., theoretically, would be $0.0000055 \times 40 \times 50 = 0.011$ ft., which is about $\frac{1}{8}$ in. In several cases the speaker has had occasion to check this theoretical contraction in actual concrete structures, and has found that it agrees closely enough for practical purposes. In one case, for example, he measured the contraction in a long, reinforced concrete, freight shed in which joints had been left at intervals; another case was in a large reservoir bottom, which was free to expand on one side; a record of the tests in the Croton Dam has been published.*

The necessity for frequent joints, in the first place, is to keep them small in size, and, in the second place, to prevent irregular cracks from opening up between them. There are certain patents on the market for steel-bound joints, which prevent chipping at the edges. It is a ques-

* *Transactions*, Am. Soc. C. E., Vol. LXI. p. 399.

tion, however, whether it is not more economical to place the joints at fairly close intervals, except where the road traffic is very heavy. Mr. Thompson.

The question of expansion requires very little consideration. Many concrete pavements are built with open joints filled with a bituminous mixture to permit expansion. In ordinary cases, where the pavement is on a uniform grade, this is not necessary, because any expansion will be taken up by the concrete itself, usually by producing compressive stresses.

Many failures of concrete pavements are due to the poor quality of the aggregates. Not only must the sand of the aggregate be clean in appearance, but it also should be subjected to actual test. Sand which passes even close inspection has been found in a great many cases to fail to set properly in mortar or concrete. A very small, almost insignificant, quantity of vegetable matter in the sand—a quantity which cannot be determined by the eye—may prevent the concrete from hardening. An especially good, fine aggregate is particularly necessary in the wearing surface of a pavement, because of the extremely hard usage to which it may be subjected. It is absolutely necessary, therefore, in any pavement used as a wearing surface, to test the sand. A mechanical analysis test is of value to determine the quantity of very fine material, which is especially detrimental to a wearing surface. In addition, however, there should always be a test of the strength of the mortar, made up into briquettes, or cubes, in the proportion of 1 part cement to 3 parts sand, and these specimens should be compared with similar ones made with the same cement and standard Ottawa sand. For the fine aggregate for a wearing surface, the strength of the mortar containing the sand in question should equal that of the standard sand mortar.

E. H. THOMES, M. AM. SOC. C. E.—The results obtained with the oil-cement, concrete section of the experimental pavements constructed on Hillside Avenue, Jamaica, N. Y., in August, 1911, by the Borough of Queens, in co-operation with the United States Office of Public Roads, may be of interest. Mr. Thomes.

About May, 1912, a number of depressions from 1 to 2 ft. in diameter, and from ½ to 1½ in. deep, had developed in the surface. On account of the traffic, it was impracticable to make repairs with Portland cement, and, therefore, this section was covered with a bituminous seal coat of about ⅔ gal. per sq. yd., applied by Tarrant hand-pouring pots and covered with sand and screenings (0.01 cu. yd. per sq. yd.). The whole section was first thoroughly cleaned by hand-brooming—ordinary, factory brush brooms—and the larger depressions and expansion joints were painted with tar asphalt, composed of Tarvia A mixed with about 15% of oil asphalt. A layer of ¾-in. stone was placed in the deeper, and one of dustless screenings in the smaller, depressions.

Mr. Thomes. The whole surface was then covered with a seal coat. Tarvia A was used from Station 0 to Station 0 + 48; tar asphalt from Station 0 + 48 to Station 1 + 52 and from Station 1 + 67 to Station 1 + 73; and Texas asphalt 55 from Station 1 + 52 to Station 1 + 67. The asphalt was applied first in a thin paint coat of 1 part asphalt to 2 parts gasoline, and then covered with the asphalt cement. Sand covering was used from Station 0 + 24 to Station 0 + 80, screenings from Station 0 to Station 0 + 24 and from Station 0 + 80 to Station 1 + 28, and dustless screenings or stone chips from Station 1 + 28 to Station 1 + 73.

In January, 1913, the Tarvia A had scaled off in a few spots, the tar asphalt was about one-third worn off, and the asphalt about one-fifth gone. There is very little apparent difference in the results obtained with the sand, screenings, and stone chips. The sand appears to give the same result as the stone chips, at one-third the expense. At the deeper depressions, the bituminous patches pushed out into waves during the summer.

A 2-in. depression at Station 1 + 73 was cut out and filled with 3-in. creosoted wood blocks with asphalt-filled joints. The wood blocks at this point, along the trolley track, and in the two-course expansion joint at Station 0 + 97, have given good satisfaction, but they are expensive.

A traffic census taken May 18th, 19th and 20th, 1912, from 7 A. M. to 11 P. M., showed an average daily traffic of 3 330 vehicles, of which 90% was motor traffic.

The speaker has inspected a number of concrete pavements between Boston and Chicago and has not seen any which have been down for any length of time and are satisfactory for heavy traffic. Some of the Blome pavements in Chicago, Washington and New Haven, have cracked badly. Most of the concrete pavements in New England have cracked and worn in holes, and have been coated with tar and grit.

A concrete pavement is defined by some engineers as one having a cement-concrete wearing surface, and by others as concrete with a thin bituminous wearing surface. The type referred to under discussion should be clearly stated.

There may be places and conditions where each type is advisable, but it is wise to proceed cautiously with the ordinary class of concrete pavement, especially in the climate of New York. A good, rich, one-layer, concrete pavement, uniformly constructed with a smooth surface and covered with a thin bituminous mat, seems to have some advantages. A good example of this type was constructed in the summer of 1912 by the Hassam Paving Company on the Jericho Turnpike, on Long Island, about one mile east of the New York City limits.

Expansion joints are not advisable in grouted stone block or wood block pavements in which proper longitudinal expansion joints are provided, and it would seem that the same should apply to concrete pavements.

PHILIP P. SHARPLES, ESQ.*—In the application of refined tars on old concrete pavements, the question of adherence is very much harder to solve than in the case of new pavements. On many pavements where there is a great deal of dust, both brought on and due to the actual grinding up of the concrete, it is extremely difficult to obtain a clean surface on which to put the tar. Mr. Sharples.

If the pavement is dampened before the application of the refined tar, it is very important that absolutely all traffic be excluded until there has been a chance for the moisture to dry out from under the surface of the tar. Otherwise the tar does not adhere well, loosens, and will not give good results. In dampening the pavement no free water should be left on the top of the concrete, for in that case, the water tends to float the tar, preventing a good bond. The concrete should be allowed to dry partly, be squeegeed off, or treated in some other way so that no excess of moisture remains.

The tar should be applied in two thin coats. A slight coating of sand or screenings over the first coat is necessary, in order to allow the second coat to be applied. The second coat is filled with sand, screenings or pea stone. In this way a surface about $\frac{3}{8}$ or $\frac{1}{2}$ in. thick is built on top of the concrete. To insure a good wearing surface, it is essential to embed in the tar a hard mineral matter which will resist abrasion.

In repairing old concrete pavements, pot-holes must be considered. It is absolutely impossible to repair pot-holes with cement-concrete in an economical way. It has been found satisfactory, however, to use tar concrete, but, in doing so, it is important to use stone which will be practically as large as the hole is deep. If fine material is used, the traffic will soon force the tar mixture out of the hole.

L. P. SIBLEY, ESQ.†—It has been suggested that the concrete should be moistened immediately before the application of the bituminous material. It seems to the speaker that there is a great difference between the entire body of the concrete being damp, or dry, and simply sprinkling the concrete immediately before applying the bituminous material. If the entire body of concrete is damp, it seems as if the results must be at least uncertain; but if it is dry, the moisture caused by the light quantity of water sprinkled on the surface would be sufficiently absorbed by the concrete so as not to interfere with the bond between the latter and the bituminous material. The road should be kept closed to traffic for a few hours in order to permit of this absorption. Mr. Sibley.

In the case of bonding between two layers of tar, when the first layer has been covered with screenings of sand, it is very important that these screenings be free from dust or any fine material, no particle

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Mr. Sibley. of which should be less than $\frac{1}{8}$ in. in size. When the bond is thus constructed, there will be no blanket of dust or fine material over the first layer of tar to prevent the second layer from uniting solidly with it.

Mr. Whinery. SAMUEL WHINERY, M. AM. SOC. C. E.—In the speaker's opinion, every concrete roadway pavement should be laid in two courses—a foundation and a surface course. The same functions are required as in other roadway pavements, that is, strength to support loads, and density and hardness to resist surface abrasion.

The surface course of a concrete pavement should be compounded and laid with something like the same care, skill, and thoroughness as the wearing course of an asphalt pavement. As a rule, this has not been done. Where the second or top course has been used, it has been laid more or less carelessly, with insufficient regard to quality of materials, uniformity of consistency, and thorough work.

Concrete pavements are not suitable for streets of heavy travel. They should never be used where a foundation of 4 in. of ordinary concrete and a surface course of 2 in. of special surface mixture, will not be ample to carry the loads and stand the abrasion of travel. There are, in every city, a large number of streets on which a properly constructed concrete pavement will give entire satisfaction. On such streets it will prove durable, dustless, possess most of the desirable qualities of a first-class roadway pavement, and give a larger return per dollar invested than any other kind of pavement.

The speaker agrees with Mr. Thompson in regard to the necessity of using only the best materials, and of giving special attention to the quality of the sand, which should be thoroughly tested. The hardness and toughness of the stone used in the top course is also an important consideration. The speaker specifies that the size of the stone shall range from that which will pass a screen of $1\frac{1}{4}$-in. mesh to that which will be held on a screen of $\frac{1}{2}$-in. mesh. The fine material and dust is objectionable, because of its tendency to segregate in the mass and because its varying quantity is likely to prevent that uniformity of mixture which is highly desirable. He requires that the sand shall be screened, that it shall be of grains of such size that 75% of the whole will fail to pass the No. 30 sieve, and that it shall be tested with regard to the strength of mortar made with it. This is important in view of recent unsatisfactory experiences with apparently good sand. A ratio of 1 part of cement to 2 parts of sand for the mortar is probably rich enough. In some recent specifications the speaker has called for ratios of 1:3:6 for the foundation course and 1:2:3.75 for the surface course, but in the compacted mass the volume of mortar should exceed that of the voids in the stone by from 7 to 10 per cent. The ideal surface-course mixture is one in which the largest practicable ratio of the mass is stone with sufficient strong mortar to hold the fragments

firmly in place. The speaker tries to insist that this surface mixture shall possess great uniformity in composition and consistency. This requires: careful measurement of all the materials, including the water; that special care be taken to prevent segregation in the mixer or on the street; and that it shall be properly and uniformly graded and compressed to a true surface on the street; in short, that especial care shall be taken to make a concrete as nearly perfect as possible. Mr. Whinery.

It is very important that the surface course be laid and tamped on the foundation course before either begins to set. This requires that the construction of the two courses be carried on simultaneously.

The surface course should be finished with a roller, not only to perfect the consolidation, but to secure a true surface, which latter is nearly as important as in the case of asphalt pavement.

Finishing the surface with neat mortar or by troweling should be prohibited.

Our knowledge relative to expansion and cracking is as yet meager. Concrete pavements often crack where apparently ample expansion joints have been provided, and frequently where least expected. Where these natural cracks or joints occur, the wear along their edges, as a rule, is less than along those of artificial expansion joints. This is probably due to the fact that the wood or metal forms used for making the joints prevent the same uniformity of composition and density of the concrete along them as in the body of the work. To prevent this, it is better not to use such joint forms, but to cut the expansion joints through the concrete after it is laid. It is an open question at present whether it is not better to omit all expansion joints (except along the curb) when the pavement is laid, and to let the concrete select and make its own expansion (or rather contraction) joints. These cracks should then be filled with bituminous cement, after being cleaned out as well as possible with proper tools and by water jets from high-pressure hose.

The question of the advisability of applying a coating of asphaltic oil to the surface of the pavement, is not yet settled, but there is every reason to believe that, if suitable material is used and the work is properly done, it will be decidedly advantageous.

Harold Parker, M. Am. Soc. C. E.—A concrete pavement is most desirable, provided it is properly laid; but, to obtain a uniform mixture and apply it uniformly all over the road is a problem not easy of accomplishment. Mr. Parker.

To secure a uniform concrete mixture on a road, the stone should be of absolutely uniform thickness, and rolled down so that the road is finished, as to cross-section and quantity of stone, before any cement is added. Whether mixtures are made on a board or in a machine, the very fact that the concrete has to be transported and put on the road

Mr. Parker. in batches, destroys its uniformity, because of the difference in the specific gravity of the materials used. A perfectly uniform road, therefore, is impossible. This can be remedied in a measure by the care that is used in making the mixture and putting it down, but the only reliable concrete road is made, as the speaker has stated, by placing the stone without binder on the road bed and rolling it thoroughly before the cement is applied.

A properly constructed concrete road is the most indestructible surface that can be built except a stone pavement. Wherever the traffic is sufficiently heavy, or of a character to warrant it, a concrete foundation should be built for any surface.

The bituminous surface on a concrete road should be applied in very thin layers, as such a coating can be maintained at small expense. It can be put on under pressure, which gives a perfectly uniform quantity of bituminous material at very trifling expense. A defect which occurs in a road thus treated is so slight in elevation that it will not be felt by the ordinary traffic going over it, whereas a defect in a top surface of 2 in. or more, soon becomes a material one, which every vehicle feels. It also increases very fast, and disintegration once begun continues rapidly.

Mr. Kinney. WILLIAM M. KINNEY, JUN. AM. SOC. C. E.—From the examination of more than 100 concrete pavements, during and after construction, in various sections of New York, Pennsylvania, Maryland, and other States, the speaker has come to the conclusion that the use of bank-run material or crusher-run limestone is almost sure to result in failure. The aggregates should be screened dry over a No. 4 screen, and remixed in the definite proportions desired. A mixture of 1 part of cement, 2 parts of sand, and 3 parts of gravel or crushed stone (from ¼ in. to 1 in. in size), will give the best results under general conditions. Though a 1 : 2 : 4 mixture might be considered better to fill the usual requirement of the ratio of fine to coarse aggregate, the excess mortar in a 1 : 2 : 3 mixture will be a distinct advantage in finishing, and, under most conditions, will be satisfactory.

This, of course, presupposes a one-course pavement, which should be selected in all cases where the aggregate available, in the territory in which the pavement is to be constructed, is suitable for a wearing surface. Good practice would recommend the two-course pavement only in places where local aggregate was suitable for the base concrete, but not for the wearing course. In such cases the cost of the pavement might be reduced considerably by shipping in only enough of the more satisfactory aggregate for the wearing course.

The use of steel trowels on a concrete pavement should be prohibited. The wooden float used after the concrete has been struck off to the proper grade with a straight-edge is amply sufficient, and does

not draw the fine material to the surface like the steel trowel. The presence of fine material on the surface is objectionable from the wearing standpoint, and also because of increased slipperiness. Mr. Kinney.

The protection of the concrete from premature drying out is an important feature of work of this type. As soon as the concrete becomes sufficiently firm, a canvas cover should be spread over the finished pavement and kept moist. This cover may be removed the next morning, or earlier, if the concrete is sufficiently hard, and the pavement covered with at least 2 in. of sand or dirt which should be kept sprinkled. The wearing quality of a pavement, well laid and of good materials, is often greatly reduced by failure to appreciate this one point of proper protection to the hardening concrete.

Regarding bituminous coatings for concrete pavements, there is this to be said in general. The coating will wear off sooner or later, and conditions in the United States are such that we cannot hope for the immediate replacement of this coating. It is essential, therefore, that the concrete be laid with the same care and attention as if no surfacing were to be applied. There is no hope for a road consisting of 6 or 7 in. of poor concrete and ¼ in. of tar or asphalt sprinkled with sand. The question of the application of bituminous surfacing should be considered carefully, as it is certain that methods of application which work successfully with tars do not work well with asphalts, and *vice versa*.

JAMES OWEN, M. AM. SOC. C. E.—In building the Plank Road from Newark to Jersey City, N. J., on the salt meadow which had been filled up to reduce the vibration, it became necessary to provide a roadway during a certain portion of the winter of 1911-12. Mr. Owen.

As a matter of economy an 8-in. concrete pavement was laid, with the idea of allowing the traffic on it during the winter and then using it in the spring for a foundation for a permanent pavement. It was about 8 in. thick and about 20 ft. wide on the fills. After the road was partly finished on top, traffic was allowed on it, with the result that the pavement was ground up and went to pieces in about three weeks.

At that time the failure was attributed to some details of the construction and to the very heavy travel. During the summer of 1912 a granite block pavement was laid on one side, with cement grouted joints, under the usual specifications. The grouting went to pieces, although the travel was not allowed on it for from 10 to 20 days after it had been applied. It was suggested that the vibration of the road was the cause of the failure of both sections. It is evident that, in cases where there is a possibility of vibration, the bond of the cement will be impaired and the efficacy of the work destroyed.

COST RECORDS AND REPORTS.

Mr. Lewis. NELSON P. LEWIS, M. AM. SOC. C. E.—The subject of cost records and reports may be considered from two aspects, the professional and the scientific.

There can be no doubt of the right of the professional man to profit by discoveries and inventions resulting from his own experiments and researches, provided he does not in a professional capacity advise the use by his clients of appliances or processes on which he holds patents and receives royalties. The idea, however, that he may regard the results of his observations and the lessons to be drawn from his own successes and failures as his stock in trade is repugnant to all who appreciate the dignity of professional work and the necessity of high professional ideals. This is especially the case with one who occupies a public office and whose experiments are conducted with public funds. It is true that while some are able to profit by the mistakes of others, there are, perhaps, more who must make the same mistakes themselves before they can learn to avoid them, and, unfortunately, there are still others who appear incapable of learning much either from the mistakes of others or from their own. That is no reason, however, why they should not be given the opportunity to do so. Believing that the professional obligation of the engineer to make public the results of his own experience for the benefit of others will be conceded, this aspect of the subject will be dismissed without further comment.

Our chief interest, then, so far as this discussion is concerned, is the scientific value of cost records and reports. If they are unscientific and inaccurate, they are worse than useless; they are misleading, not only to those who examine them, but also to those who prepare them. They may be accurate as far as they go, and still be unscientific and all the more dangerous because they bear on their face certain evidences of painstaking accuracy, while, owing to their failure to give the precise circumstances under which the work was carried out, the omission of overhead or other charges, and especially owing to a disposition to ignore certain unsatisfactory features of the completed work due to carelessness or lack of foresight, which the engineer in responsible charge is reluctant to admit, erroneous conclusions are likely to be drawn.

The aim of the speaker in these introductory remarks will be, not to suggest certain forms of cost records and reports, but to outline briefly some of the fundamental considerations which should govern their preparation and publication. First, we must draw a sharp distinction between cost records and accounting—two very different things. The main object of accounting is to permit of intelligent bookkeeping, to distribute the different items of cost among various

accounts or appropriations, to know about how much the work has cost, and to distribute that cost with a refinement and an apparent accuracy that will delight the heart of the accountant. If some items are found to have been charged up in a manner inconsistent with the principles laid down by men who have never done any real constructive work, there is ground for caustic criticism, an opportunity for which is often productive of holy joy, which, however, is judiciously expressed in terms of indignation. Mr. Lewis.

The object of cost records, on the other hand, is to determine how much the work is costing, and to check or correct leaks here or there, which may be due to improper organization or to ill-adapted plant or equipment. Such defects will not only add to the cost of the work, but they are frequently of such a character as to impair its quality when finished. Of course, when an intelligent system of cost records is first introduced, it cannot be expected to have an immediate effect on the particular job to which it is first applied. It will, however, indicate where improvement can be effected, and it should not be long before the system can be perfected so that the engineer can put his finger on the weak spots very quickly and correct the trouble before the record for the entire job shall have been spoiled.

Road construction and maintenance are usually paid for from public funds, and the engineer in charge of such work is almost invariably hedged about with legal restrictions and limitations, which have been placed on his authority, particularly as to the control of labor and his inability to buy in the cheapest market or to secure needed materials or supplies promptly in an emergency. It is not unnatural, under these circumstances, that he should come to regard cost records as of academic, rather than of practical, interest and value.

In the speaker's opinion, there is nothing that will operate more effectually to remove, or at least mitigate, these restrictions and limitations than an accurate, scientific presentation of the facts, with the reasons why. Even in the public service, it will be possible to select a certain number of skilled and common laborers who are fairly efficient, and if these can be grouped together and the results obtained with them compared with those of a gang of less industry and capacity, and the responsibility for low efficiency and greater cost clearly and publicly placed where it belongs, it is not unlikely that popular opinion will soon insist that the man who is responsible for results will be given a chance to produce them.

Efficiency is an impressive sort of word, and efficiency engineering sounds like a particularly dignified and useful branch of the Engineering Profession. It has naturally attracted a considerable number of men, many of whom have had little actual experience and whose capacity for destructive criticism is far more conspicuous than their

Mr. Lewis. ability to do constructive work. It would be a great mistake, however, to conclude that efforts to promote efficiency are not worth while. They are worth while, provided they result in a decrease of the actual unit cost of work and at the same time improve its quality. Unless this is the result, "the game is not worth the candle." If cost records do not point the way to economy without sacrifice of quality, they have only an academic value and are not worth while. If reports contain only a record of the number of contracts which have been let, the names of the contractors, and the amounts expended from each account, with the unexpended balances in each, they have no engineering value. If they are framed so as to make a favorable showing of the quantity of work done in a given time and a low cost per square yard or per mile, and at the same time omit data which might indicate that these results were accomplished at the sacrifice of quality, and if they lay emphasis on the successes and ignore the failures, they are dishonest.

Cost records of road work should indicate as clearly as possible the proportion of the expense chargeable to:

1.—Permanent betterments, such as land purchases, grading, the improvement of lines and grades, masonry and steel bridges, and culverts. This part of the work once done may be considered permanent or sufficiently durable to outlast more than a single generation.

2.—Curbing, gutter pavement, fencing, guard-rails, wooden bridges, concrete foundation, planting, etc., all of which may need periodical repairs, but will probably last twenty years at least.

3.—The road surface, which will begin to deteriorate at once, and will need constant attention and periodical renewal.

For each piece of work the records should include:

1.—The character and first cost of the materials;

2.—Cost of delivery on the work, with kind of transportation and distance hauled;

3.—Cost of labor of all classes, and the quality of the same;

4.—Cost or present value of plant and equipment, with allowance for depreciation due to the work under construction and not previously marked off;

5.—All overhead charges, including engineering and inspection;

6.—The cost of bonds, permits, etc.;

7.—All delays due to weather, failure to receive materials, strikes, or other causes;

8.—A precise description of the methods used and of the surface treatment of the road;

9.—A statement as to the results obtained, the probable causes of failures or unsatisfactory work, and the means used to correct or remedy them;

10.—The manner in which the funds to pay for the work are raised, whether by cash appropriations, by the issue of bonds, with length of term and rate of interest, or by money advanced in anticipation of the collection of assessments for benefit. Mr. Lewis.

Although this brief outline may have contributed nothing of value, it is hoped that it will serve the purpose of an introduction.

L. L. Tribus, M. Am. Soc. C. E.—The value of cost records is well illustrated in the Borough of Richmond, City of New York. In organizing its work the following queries were considered: Mr. Tribus

1. What is really needed to be done?
2. Was similar work done in preceding years necessary?
3. What had such work cost locally and in other places?
4. What should it cost?
5. How can appropriations and expenditures be controlled, so as to secure work needed and at proper cost?

Some few years ago, the City of New York as a whole felt that, in connection with its highways and sewers, there was a lack of reliable information on which the appropriating bodies could act. From its cost records, maintained for years, and practically the only ones in the city, the Borough of Richmond furnished most of the information from which appropriations were made thereafter for work throughout the Greater City.

In carrying out the plans, if a certain class of work costs less in one district than in another, an investigation is made. If the difference is large, there is some special reason for it, and the records usually show what that reason is, because conditions as to haul, temperature, and a number of other items which have an influence in the destruction or preservation of roads and sewers and in their maintenance, are known.

The speaker can testify that cost records and intelligent reports, with the giving of needed information to the men, produce results of economic value, fully within the term, "efficiency," as defined by Mr. Lewis.

W. W. Crosby, M. Am. Soc. C. E.—With the growing demand for efficiency in all engineering work, with the increase in attention generally to this feature, and with the recognition of the dependence on the factor of cost or expense for measuring the value of the results, it seems to have become necessary to regulate somewhat the acquisition and reporting of cost data. Up to the present, not only have the costs of details of road work been almost as variously reported as there were reporters or details, but a similar variation has also existed in the statements of costs of the work in the aggregate or as a whole. Mr. Crosby.

For instance, if one desires to know what the total expense per mile

Mr. Crosby. has been to the State of Massachusetts for its completed State roads, and how that same cost unit of New York compares with the Massachusetts figures, no satisfactory, or even approximately correct, answer can be had, because of the different systems used in accounting for the road funds of the two States. The speaker had occasion, a year or more ago, to compare the cost per mile of the preliminary road surveys and plans in Maryland with those of some other State doing similar work, but he was able to find only two instances in the country where even approximate costs of this item could be had, one of these being a "post-mortem" by a special committee engaged for the purpose.

Take the simple case of a single item of road work—that of water-bound macadam. Speakers here and reporters elsewhere have variously calculated it, in some cases naming simply the price paid to a contractor; in others, where the work was done by "force account" and the machinery was rented, the rental actually paid for the machinery was included, but no depreciation, profit, or overhead charges were embraced in the figures; and, in still other instances, where perhaps the machinery was owned by the authorities, no allowances for it, nor even for the supervision, were calculated in the costs given. Yet the effort was, and is frequently, made to draw close comparisons between the resulting "cost" figures obtained by each method.

The speaker took occasion two years ago to invite attention to the importance of this matter, because of the readily apparent interest manifested in the statements of costs made by the various speakers. Further, it will probably be admitted that the satisfactory selection of a pavement to meet any local conditions will be largely affected, if not determined, by proper consideration of the cost factors. Hence the importance of accuracy in arriving at the arithmetical equivalent of these factors in the equation; and the narrower the margin, the greater the necessity becomes.

To avoid being misunderstood and considered perhaps as a "hair splitter," allow the speaker to state that exactness in this matter is not his goal, but rather "relative" accuracy. That is, he believes that almost all values are relative; that, in road matters, their dependence on other factors, such, for instance, as traffic, weather, and other conditions—impracticable of either exact determination or expression—relieves the necessity of absolute exactness, and that ordinary accuracy and uniformity are all that are necessary or desirable for purposes of satisfactory comparison, which is the end desired.

Therefore, in the interest of uniformity and for general benefit, attention is invited to the system for the accounting of road expenditures established in Maryland in the spring of 1912 by the speaker with the assistance of a reputable firm of expert accountants (Haskins and Sells, of New York). Although complete information in the matter

could not be appropriately given on this occasion, the principles involved may be indicated briefly. They are: Mr. Crosby.

First.—Charge to any item all the expenses that can be accurately determined as belonging properly to that item.

Second.—Charge to any item the cost of tools, materials, machinery, etc., consumed by that item. In the cases of tools or machinery having a life greater than their period of use for any item, then charge to that item, in lieu of depreciation, rent, interest, etc., a flat rate of 5% per month (or if preferable for any reason, 0.2% per day) for the time used on the item in question.

Third.—Such expenses as are unassignable clearly to any items, or indivisible among a group of items, are to be pro-rated among such items or groups in the proportion that the individual totals of the costs directly chargeable to such items or groups bear to the aggregate of such direct charges.

These principles can be carried into the details of the work as far as desired. If carefully applied, they seem to permit of sufficiently accurate results to enable comparisons of cost to be made intelligently, a thing now most difficult, if not impossible, between different localities not under identical authorities.

Two of the principles may seem to be simple and not new; but the speaker has found only one or two instances of even an approach to uniformity in their application, though he has searched far and wide.

The second principle, regarding charges for machinery, is probably the most novel of the three. It will not be disputed that a charge should be made for tools and machinery, but what this charge should be, and how it should be applied, may cause some discussion. The rate suggested by the speaker corresponds fairly closely with prices secured by private owners; it is simple and convenient, and to the speaker does not seem to be unfair. He admits that it will probably seem too high at first, but after experience with the relatively short life of road machinery, the desirability of keeping it in first-class condition, the length of time it is frequently idle, consideration of interest charges, obsolescence, etc., he thinks the rate suggested is wise and safe. It should be stated, perhaps, that this 5% per month is in addition to bills for minor repairs which are chargeable to the work directly.

In illustration of the application of the foregoing, the speaker submits two graphical representations of the subdivision of cost or expense into items of ordinary use—Tables 1 and 2. Table 2 shows the figures and percentages for each item or group of items in relation to the total of each group, and of the whole expense of the State Roads Commission of Maryland for 4 years (1908-'09-'10-'11), aggregating $4 250 000.

Mr. Crosby.

He also submits a subdivision (Table 3), on the same basis, of the part of this expense for completed work, showing its division between the physical items ordinarily reported by the various authorities, and of general public interest.

TABLE 1.

Cost.	Administration and Legal........	Commission's (or Board's) Salaries and Expenses. Commission's (or Board's) Office Force, Salaries. Commission's (or Board's) Office Expenses. Commission's (or Board's) Counsel, Salaries, Fees and Expenses.
	Engineering, General.............	Chief Engineer's Salary and Expenses. Chief Engineer's Office Employees' Salaries. Chief Engineer's Office Expenses. Chief Engineer's Instruments and Repairs. Chief Engineer's Laboratory Investigations.
	Preliminary.......................	Engineers in Charge—Salary and Expenses. Survey Parties—Salary and Expenses. Office Employees' (Draftsmen, etc.) Salaries. Office Expenses, Stakes, etc.
	Construction. (Reconstruction) (Maintenance)	Engineers in Charge—Salaries and Expenses. Office Employees—Salaries. Office Expenses. Inspectors—Salaries and Expenses. Superintendents—Salaries and Expenses. Foremen, Labor, Teams, etc., Pay of Advertising. Materials Consumed. Expense for. Use of Equipment, Rental for and Repairs. Rights of Way and Damages. Advertising. Miscellaneous.
	Equipment.......................	Expense for. Transportation of and Establishment. Renewals and Depreciation. Salaries of Men in Charge of, etc.

In reference to this, let it be said that it was fully realized that seldom, if ever, are two appropriations made along identical lines, and that there will always be a necessity for accounting for the funds separately. Provision has been made for this matter, also, in the new Maryland system, and those interested in the bookkeeping are referred to the recent Report of the Roads Commission for further information on this point.

The foregoing is applicable to the records and compilations of the first cost of road work. As to the final cost of any particular piece of work, it is evident that such is the sum of the first cost and the maintenance and interest charges, or the "long-run cost."

The "long-run cost" the speaker conceives is made up thus:

Long-run cost	Interest on first cost. (When first cost is met by bonds.)	
	Sinking fund charges.	
	Maintenance expenses (made up periodically along lines prescribed above for first costs).	on: Surfacing, Earthwork, Culverts, bridges, and drains separately, and Total.

Mr. Crosby.

TABLE 2.

Total	Division	Subdivision	Item	Percentage.	Amount.
Total Expense $4 422 520.54.	Administration and Legal $62 910.51 1.4 per cent.		Commission Salaries and Expenses	50.33	$ 31 666.42
			Commission Secretary and Office Employees' Salaries	23.41	14 728.05
			Commission Office Expenses	16.33	10 273.71
			Counsel's Salary, Fees and Expenses	9.93	6 242.33
	Engineering General $56 318.72 1.3 per cent.		Engineer's Salary and Expenses	27.81	15 660.59
			Office Employees' Salaries	28.62	16 118.02
			Office Expenses	37.49	21 116.22
			Shop Labor and Material	5.01	2 820.29
			Tests and Investigations	1.07	603.60
	Preliminary and Construction $4 126 911.46 93.3 per cent.	Engineering $56 056.90 1.3 per cent.	Engineer's Salary and Expenses	27.96	15 675.81
			Engineer Inspector's Salary and Expenses	38.53	21 598.72
			Office Employees' Salaries	31.54	17 680.85
			Office Expenses	1.97	1 101.52
		Preliminary $59 907.12 1.5 per cent.	Survey Parties	34.06	20 405.63
			Draftsmen	65.94	39 501.49
		Construction $4 010 947.44 97.2 per cent.	Rights of Way and Damages	6.91	277 157.76
			Grading	15.45	619 652.83
			Surfacing	56.10	2 250 318.16
			Bridges and Culverts	12.65	507 214.33
			Drains	1.20	48 103.13
			Advertising	0.07	2 976.87
			Inspection	2.44	97 677.18
			Superintendence	0.40	16 242.81
			Final Surveys, Estimates and Plans	0.03	1 100.00
			Miscellaneous	0.37	14 789.26
			United Railways Company's Work	4.38	175 705.11
	Reconstruction and Maintenance $128 949.47 2.9 per cent.	Engineering $14 293.25 11.1 per cent.	Engineers' Salary and Expenses	19.07	2 725.21
			Engineer Inspector's Salary and Expenses	50.82	7 263.66
			Office Employees' Salaries	23.93	3 421.05
			Office Expenses	6.18	883.33
		Reconstruction $16 378.92 12.7 per cent.	Labor and Materials	33.65	5 512.12
			Team Hire and Use of Equipment	21.46	3 515.02
			Superintendence	32.20	5 274.14
			Inspection	12.69	2 077.64
		Maintenance $98 277.30 76.2 per cent.	Labor	22.20	21 820.41
			Materials	57.31	56 320.75
			Team Hire and Use of Equipment	13.66	13 419.10
			Superintendence	5.77	5 675.98
			Inspection	1.06	1 041.06
	Equipment $47 430.38 1.1 per cent.	Construction	Rental charge for average time at 5% per month equals		14 563.00
		Maintenance	Rental charge for average time at 5% per month equals		595.00
		Reconstruction	Rental charge for average time at 5% per month equals		800.00

NOTE.—The figures in this table are given to show the actual distribution of the total expenditures by the State Roads Commission to December 31st, 1911. The segregation into items of work done is given on pages 28, 29, 30, and 31 of the report.

Mr Crosby.

TABLE 3.—SUBDIVISION OF EXPENDITURES BY THE STATE IN THE YEARS 1908

County.	Contract No.	Name of road.	Description.	Miles of road.	CONSTRUC				
					Preliminary surveys and plans.	Grading.	Surfacing.	Bridges and culverts.	Under-drains.
......	..	....	"State Roads".......	153.13	$11 651.93	$269 407.14	$1 042 058.56	$139 205.94	$27 432.64
......	..	....	"State Aid Roads"...	26.89	2 015.15	59 656.02	164 107.58	49 320.26	3 786.70
......	..	....	"Roads and Bridges"	13.28	1 607.62	23 234.62	123 377.54	12 446.72	1 502.28
......	..	....	"State Road No. 1"..	0.55	123.63	903.53	20 928.11	287.04	482.31
Totals	..	....	All kinds............	193.85	$15 398.33	$353 201.31	$1 350 471.79	$201 259.96	$33 203.93

Consequently, for recording the long-run costs in Maryland, cards were designed as shown by Table 4.

Lest it be thought that the speaker has, by his suggestions, simply added work and expense to the State highway authorities for the sole purpose of furnishing engineers with more accurate data, perhaps to an inappreciably good end, he may state that, on the contrary, the revision of the accounting system of the Maryland Roads Commission has resulted in at least two direct benefits:

First.—The accounts now kept give dependable information on all points likely to arise, and give it clearly, readily, and accurately; and it has been possible to secure easily and quickly from these accounts such information on other less usual points.

Second.—The annual expense of keeping the books of the Maryland Commission has been reduced by 60% or more.

The speaker believes that the Maryland system as adopted is readily applicable to other communities, and, when thus applied, would generally be found to be beneficial. The particular point he wishes to make is that far greater uniformity than at present exists in cost recording and reporting is now, not only desirable, but necessary, if as engineers we are to be able to do our full duty.

Connected with the foregoing, concerning cost figures, the speaker has some records of expenditures and of traffic on a particular road, which records, together with some deductions or conclusions of his own, he submits, as follows:

The experimental pitch-macadam pavement on Park Heights Avenue, near Baltimore, Md., is now entering its fourth year of service. Some of the sections were completed during the summer and autumn of 1909 (Sections 1 to 9 and 19 to 27, inclusive), and others during

ROADS COMMISSION OF MARYLAND FOR COMPLETED ROADS TO 1912, INCLUSIVE.

Mr. Crosby.

TION.								
Inspection and superintendence.	Miscellaneous.	Total.	Cost per mile.	Rights of way and damages.	Total, including rights of way and damages.	Administration, legal and general engineering expenses.	Total cost of road.	Cost per mile.
$37 538.25	$7 321.39	$1 534 615.85	$10 021.65	$3 032.09	$1 537 647.94	$70 088.24	$1 607 736.18	$10 499.16
11 841.38	1 235.51	291 962.60	10 857.67	......	291 962.60	13 189.89	305 152.49	11 348.17
2 124.90	212.56	164 506.24	12 387.52	1 915.85	166 422.09	7 582.93	174 005.02	13 102.79
736.72	51.48	23 512.82	42 750.58	......	23 512.82	1 077.08	24 589.90	44 708.91
$52 241.25	$8 820.94	$2 014 597.51	$10 387.40	$4 947.94	$2 019 545.45	$91 938.14	$2 111 483.59	$10 892.36

the working season of 1910. It is thought that sufficient experience has been had with most of these sections to warrant some study of the costs, and that such a study will be profitable.

Full descriptions of the construction have already been published,* and, therefore, need not be repeated here.

The expenditures on the twenty-six sections of pitch-macadam, on the two surfaces treated with pitch, and on the single section treated with "Glutrin," are given in Table 5. The travel censuses, showing the character and extent of the traffic on the road, are given in Table 6.†

On account of the rebuilding of Sections 1 and 3 late in 1911 (completed early in 1912), it is thought best to omit these two sections from detailed consideration now, simply remarking that at present they are in fair condition, their defects seeming to be due, mainly, to a slight excess of pitch in spots, probably from the use of too much material as a flush coat. Section 11-A may also be omitted as of little value for deductions, as it was an emergency section pitched with an unrecorded mixture of a variety of pitches happening to be available under the exigencies of the occasion.

Let it be assumed that, in the consideration of the expenditures for the pitch work, the expenses for resurfacing the old macadam, or for putting it in condition to receive the pitch treatment, do not enter; that the unrecorded (and difficult, if not impossible, to estimate) saving from not water-binding this macadam resurfacing can be neglected; and that the maintenance expenditures on the shoulders, earth side-road, and ditches should be eliminated where separable. Then Table 7 shows the net charges on the pitch-macadam.

* *Transactions*, Am. Soc. C. E., Vol. LXXIII, p. 74; and Vol. LXXV, p. 598.

† An explanation of the "Factors" used may be found in "A Simplification of Traffic Censuses for Purposes of Comparison," *The Surveyor* (London), March 10th, 1911, p. 364; or *Municipal Engineering*, March, 1911, p. 167.

Mr. Crosby.

TABLE 4.—SUMMARY OF MAINTENANCE COSTS.*

Road, ..., Sec. ......, Built under Contract No......., in .... County.

Completed Costs: Surfacing (sq. yd.) = $. Earthwork and Miscellaneous = $.

Bridges, Culverts, and Drains = $.

Costs.

Period.	Surfacing.			Earthwork.			Culverts, Bridges, and Drains.			Grand total.
	Interest on cost and S. F. charges.	Expense of repairs and maintenance	Total.	Interest on cost and S. F. charges.	Expense of repairs and maintenance.	Total.	Interest on cost and S. F. charges.	Expense of repairs and maintenance.	Total.	
Int. at 6% (simple)..										

*Form for recording on cards.

The charges do not include any allowances for "Overhead Expenses," "Administration," or "Engineering," but cover all expenses for materials, labor, inspection, tools, etc., on the work, rental (or allowance therefor) on machinery used, etc., and in make-up follow the lines adopted for accounting by the State Roads Commission of Maryland.* Mr. Crosby.

The following conclusions are drawn from these data and the speaker's experience with the work and its results:

Section 29, having been newly resurfaced with a fairly hard limestone water-bound macadam in 1909, and having shown by the summer of 1910 a tendency to serious deterioration under the travel on it, and since the latter date having been treated (as apparently necessary) with "Glutrin," and now being in fully as good condition as before the treatment was begun, the speaker is of the opinion that:

(*a*) A 12-ft., water-bound, limestone macadam will not support successfully travel aggregating 400 units per average day of 10 hours, and where 60% of the total travel is that of motors.

(*b*) Such a road surface can be made to sustain such travel, with physical satisfaction, by treating it with "Glutrin."

(*c*) Such a road surface can be made to sustain such travel, with physical satisfaction, by giving it a surface treatment of "cut-back Texas asphalt" (Section 28).

(*d*) An 18-ft., water-bound, trap rock macadam is incapable of sustaining, without serious deterioration in a few months, travel aggregating 2 500 units per average day of 10 hours, and where 90% of the total travel is that of motors.

(*e*) The surface treatment of such a road with a proper cut-back sludge asphalt, or a proper compound of water-gas tar, will enable it to sustain such travel, with physical satisfaction (Sections 15 and 16).

(*f*) A 24-ft. pitch-macadam, of either limestone or trap rock, will sustain, with at least physical satisfaction, travel aggregating as many as 15 000 units per average day of 10 hours, and when more than 95% of the total travel is that of motors (Sections 4 and 5).

(*g*) A 14-ft. pitch-macadam, of either limestone or trap rock, will sustain, with at least physical satisfaction, travel aggregating 5 000 units per average day of 10 hours, and when less than 15% of the total travel is that of horse-drawn vehicles (Sections 17 to 27, inclusive).

(*h*) The present indications are that the use of pitch in quantities of more than $1\frac{3}{4}$ gal. per sq. yd., in the construction of pitch-macadam, where the upper course of the macadam is to be 3 in. thick after compaction, is generally inadvisable.

(*i*) The use of a flush coat, except possibly in the cases of pitches having unusual stability under the application of heat, is inadvisable in the construction of pitch-macadam, unless the proportion of horse-drawn travel to motor travel is considerably higher than in this case.

* First Report, State Roads Commissioner of Maryland for 1908–09–10–11.

Mr. Crosby.

TABLE 5.—CONSTRUCTION AND MAINTENANCE

Section.	Material.	Width, in feet.	Area, in square yards.	CONSTRUCTION OF MACADAM PER		
				Dates of use.	Gallons used per square yard.	Cost of resurfacing.
1..	Texas	30 35 24	11 226.11	July, Aug., '09	2.39	$0.337
2..	Gulf Ref. Co. "Asphaltoil A"	24	1 936.00	Aug., Sept., '09	3.97	0.339
3..	Texas	24	1 242.66	Sept., 1909	3.22	0.336
4..	Imp. Prod. Co. "Fairfield"	24	1 173 33	Sept., 1909	3.67	0.337
5..	U. G. I. No. 4—Sample No. 1	24	1 712.00	Sept., 1909	3.12	0.339
6..	Warren-Puritan, Brand No. 10.	24	1 826.66	Sept., Oct., '09	4.19	0.333
7..	Tarvia X	24	1 909.33	October, 1909	5.40	0.337
8..	Amer. Tar Co., "Tarite"	24	1 816.00	October, 1909	4.41	0.336
9..	U. G. I.—(1909 work)	24	1 170.66	November, 1909	4.46	0.340
10..	U. G. I.—(1910 work)	24	3 232.00	May, June, '10	1.43	0.397
11..	Texas	24	5 981.33	June, 1910	1.25	0.397
11-A	Mixed—52 bbl	24	1 261.33	June, 1910	1.65	0.397
12..	Headley Man'f. Co	24	4 685.33	June, July, '10	1.70	0.397
13..	Barber Asphalt Co	24	4 202.66	July, Aug., '10	1.45	0.397
14..	"Fairfield"	24	3 184.00	Aug., Sept., '10	1.69	0.397
15..	"Fairfield Antidust"	18	5 808.00	October, 1910	0.61	0.397
16..	U. G. I. "Antidust"	18	1 100.00	Sept., Oct., '10	0.94	0.397
17..	"Sarco"	12	3 568.00	October, 1910	1.42	0.397
18..	Std. Oil (1910 work)	12	1 893.33	October, 1910	1.70	0.397
19..	Std. Oil (1909 work)	14	127.55	November, 1909	3.92	0.241
20..	U. G. I.	14	1 294.22	October, 1909	3.86	0.230
21..	Texas	14	693.77	October, 1909	4.70	0.228
22..	Gulf "Asphaltoil A"	14	976.88	October, 1909	2.95	0.229
23..	Warren-Puritan, Brand No. 17	14	844.66	October, 1909	4.71	0.224
24..	U. G. I	14	2 246.22	September, 1009	2.23	0.229
25..	Imp. Prod. Co. "Fairfield"	14	1 532.22	September, 1909	2.73	0.228
26..	Con. G. E. L. & P. Co. (Complete top of U. G. I.)	14	3 758 22	August, 1909	2.98	0.216
27..	Con. G. E. L. & P. Co	14	1 048.44	August, 1909	1.95	0.216
28..	"Texaco Special"	14	863.33	Oct., Nov., '10	1.25	0.607
29..	"Glutrin"	12	13 398.67	Nov., 1909; Oct., Nov., '10	0.45	0.318

* Length, 8.246 + miles.

† Includes maintenance of shoulders, side-road, and drains or gutters.

‡ To remedy slipperiness.

(*j*) With the use of materials susceptible to heat, or fairly so—such as most tars—the application of the pitch to the rolled stone can safely be stopped at a line parallel to and 1 ft. within the edges of the stone, and reliance can be felt that this border of the macadam, later, will be properly bound by the flow of the pitch under heat and travel.

(*k*) With the use of asphaltic or blown-oil pitches, having a "penetration" at normal temperatures harder than 150, the application of the pitch should be made fully to the edges of the rolled stone.

(*l*) The requisite penetration of the pitch into the rolled stone is obtained when the pitch reaches to the bottom of the average sized stone in the course penetrated.

EXPENDITURES ON PARK HEIGHTS AVENUE.*

Mr. Crosby.

Square Yard.		Maintenance, per Square Yard of Macadam.									
			1911.					1912.			
Cost of pitching, including shipping.	Total first cost.	1910	Earthwork and culverts.†	Painting edges.	Oiling and chipping.‡	Net repairs.	Totals.	Earthwork and culverts.	Painting edges.	Net repairs.	Totals.
$0.327	$0.664	$0.088	....	....	....	$0.9011 §	$0.9011	$0.0396	....	$0.0036	$0.0432
0.434	0.773	0.080	$0.0455	....	....	0.0000	0.0455	0.0199	....	0.0959	0.1158
0.418	0.754	0.187	....	....	....	0.9947 §	0.9947	0.0124	....	0.0044	0.0168
0.449	0.786	0.081	0.0093	....	....	0.0000	0.0093	0.0065	....	0.0031	0.0096
0.344	0.683	0.081	0.0049	....	$0.0364	0.0093	0.0506	0.0169	....	0.0034	0.0203
0.606	0.939	0.079	0.0024	....	....	0.0563	0.0587	0.0183	....	0.0484	0.0617
0.618	0.955	0.082	0.0054	....	0.0180	0.0034	0.0268	0.0075	....	0.0135	0.0210
0.605	0.941	0.080	0.0097	....	....	0.0098 ‖	0.0195	0.0064	....	0.0583	0.0647
0.454	0.894	0.091	0.0187	....	....	0.0049	0.0236	0.0088	....	0.0171	0.0259
0.242	0.639	......	0.0097	....	....	0.0080	0.0177	0.0022	....	0.0052	0.0074
0.264	0.661	......	0.0028	....	....	0.0042	0.0070	0.0018	....	0.0039	0.0057
0.262	0.659	......	0.0055	....	....	0.0298	0.0353	0.0087	....	0.0100	0.0187
0.327	0.724	......	0.0029	....	....	0.0349	0.0378	0.0059	....	0.0005	0.0064
0.325	0.722	......	0.0057	$0.0101	....	0.0000	0.0158	0.0040	....	0.0005	0.0045
0.292	0.689	......	0.0048	0.0013	....	0.0105	0.0166	0.0099	....	0.0215	0.0314
0.084	0.481	......	0.0037	....	....	0.0335	0.0372	0.0025	....	0.0157	0.0182
0.140	0.537	......	0.0070	....	....	0.0980	0.1050	0.0045	....	0.0243	0.0287
0.325	0.722	......	0.0136	0.0161	....	0.0000	0.0297	0.0209	....	0.0143	0.0352
0.287	0.684	......	0.0091	0.0281	0.0062	0.0000	0.0434	0.0278	....	0.0072	0.0350
0.410	0.651	0.087	0.0266	....	0.0484	0.2179	0.2929	0.0055	....	0.0649	0.0704
0.408	0.638	0.088	0.0683	....	0.0332	0.0513	0.1528	0.0207	....	0.0000	0.0207
0.551	0.779	0.088	0.0186	....	....	0.1805	0.1991	0.0080	....	0.0239	0.0319
0.405	0.634	0.082	0.0391	....	....	0.1851	0.2242	0.0096	....	0.0670	0.0766
0.691	0.915	0.082	0.0144	....	0.0293	0.0463	0.0900	0.0116	....	0.0062	0.0178
0.257	0.486	0.081	0.0114	....	0.0041	0.0514 ¶	0.0669	0.0093	....	0.0088	0.0181
0.353	0.581	0.057	0.0091	....	....	0.0763 ¶	0.0854	0.0119	....	0.0000	0.0119
0.303	0.519	0.057	0.0038	....	....	0.0286 ¶	0.0324	0.0064	....	0.0024	0.0088
0.227	0.436	0.057	0.0086	0.0053	....	0.0003	0.0142	0.0065	....	0.0020	0.0085
0.355	0.962	......	0.0167	0.0068	....	0.0024	0.0199	0.0290	....	0.0442	0.0732
0.074	0.392	......	0.0138	....	....	0.0308	0.0446	0.0193	....	0.0874	0.1067

§ Reconstructed, 1911.

‖ Chips hauled and spread on account of bleeding.

¶ Rolling in No. 2 stone and chipping.

(*m*) Success in the construction of pitch-macadam depends primarily on the proper compaction of the macadam particles, and is directly proportional to the success in rolling the macadam before spreading the pitch.

(*n*) The use of sand on top of the pitch is open to grave objections, and the value of its use before spreading the pitch is questionable, clean stone chips of small gravel, free from particles which will not pass ⅛-in. mesh being preferable.

(*o*) With the use of a proper pitch, there is no material advantage in closing the finished pitch-macadam to travel for a period after its construction, provided the adhesion of tires to the surface is prevented by watering, spreading an excess of grit, or by other means.

Mr. Crosby.

TABLE 6.—TRAVEL CENSUS AND

Classification.	Maryland factor used in product.	Section 1. Units on dates named per period of 10 hours.					
		Nov. 14, 1910.	Nov. 17. 1910.	Oct. 19, 1911.	May 4, 1912.	May 10, 1912.	May 11, 1912.
One-horse vehicles...........	2	376	442	438	366	608	514
Two " "	4	364	332	408	456	560	468
Three " "	6	48	48	....	30	60	48
Four " "	8	104	72	16	....	16	....
Six " "	12	24	....	12	....	....	....
Total horse traffic	..	916	894	874	1 052	1 244	1 030
MOTOR TRAFFIC:							
Motorcycles................	2	14	14	50	102	96	136
Runabouts.................	10	200	230	480	590	450	830
4- or 5-seat cars............	20	2 100	2 580	6 580	11 960	11 660	18 800
7-seat cars..................	40	1 920	2 480	5 320	9 920	5 120	9 760
Omnibuses or drays	20	40	80	440	700	760	980
Total traffic..............	..	5 190	6 278	13 744	24 324	19 330	41 536
Weather	..	Clear.	Clear.	Clear A. M. Rain P. M.	Clear.	Clear.	Clear.

TABLE 6.—

Classification.	Maryland factor used in product.	Section 2. Units on dates named per period of 10 hours.					
		Nov. 15, 1910.	Nov. 18, 1910.	Oct. 14, 1911.	Oct. 21, 1911.	May 10, 1912.	May 11, 1912.
One-horse vehicles...........	2	336	314	422	314	632	636
Two- " "	4	356	312	376	248	512	476
Three- " "	6	18	18	....	....	30	90
Four- " "	8	152	96	16	8	16	....
Six- " "	12	....	24	....	....	....	....
Total horse traffic........	..	862	764	814	570	1 190	1 202
MOTOR TRAFFIC:							
Motorcycles................	2	6	8	80	....	80	136
Runabouts.................	10	130	120	550	370	640	840
4- or 5-seat cars............	20	2 200	2 500	8 080	5 120	9 300	15 440
7-seat cars	40	1 520	2 120	5 280	5 320	9 880	11 400
Omnibuses or drays	20	120	120	640	540	840	1 060
Total traffic..............	..	4 838	5 632	15 444	11 920	21 930	30 078
Weather	..	Cloudy.	Clear.	Clear.	Rain.	Clear.	Clear.

Mr. Crosby.

UNITS ON PARK HEIGHTS AVENUE.

	Sections 17 to 21. Units on dates named per period of 10 hours.					Section 28. Units per 10 hours.		
	Nov. 22, 1910.	Nov. 26, 1910.	Oct. 25, 1911.	Apr. 1, 1912.	Apr. 16, 1912.	Jan. 16, 1911.	Apr. 10, 1912.	May 29, 1912.
	44	40	44	444	176	28	28	28
	44	28	24	748	372	4	8	12
	....	....	6	....	....	....	....	....
	....	8	8	272	152	40	24	9
	36	24	....	336	120	132	96	1
	124	100	82	1 800	820	204	156	50
	4	8	16	80	26	....	6	....
	40	20	230	680	440	....	30	1
	560	760	960	4 960	3 120	....	160	19
	480	760	2 680	2 400	1 160	....	....	5
	60	40	60	1 060	420	....	40	5
	1 268	1 688	4 028	10 980	5 986	204	392	80
	Rain.	....	Clear.	Clear. Cloudy.	Clear.	Clear. Cold.	Clear.	Clear.

(*Continued.*)

	Sections 15 and 16. Units on dates named per period of 10 hours.					Section 27. Units per 10 hours.		Section 29. Units per 10 hours.	
	Nov. 16, 1910.	Nov. 19, 1910.	Nov. 21, 1910.	Nov. 25, 1910.	Apr. 12, 1912.	Nov. 23, 1910.	Nov. 28, 1910.	Nov. 24, 1910.	Nov. 29, 1910.
	78	94	56	46	40	68	70	26	22
	100	52	52	76	36	20	40	16	12
	20	12	12	18	....	....	....	....	....
	40	8	8	....	....	40	16	24	8
	12	....	12	12	....	216	96	96	....
	250	166	140	152	76	344	222	162	42
	8	14	6	6	34	6	4	....	....
	80	100	40	50	180	30	10	10	20
	1 440	1 680	1 260	1 050	2 360	1 000	320	120	120
	1 080	1 520	1 440	1 200	760	1 480	520	80	80
	40	60	60	60	220	50	40	....	....
	2 898	3 540	2 946	2 528	3 630	2 920	1 116	372	262
	Clear.	Clear.	Cloudy.	Clear.	Clear.	Fair.	Cloudy. Rain.	Fair.	Cloudy.

Mr. Crosby.

TABLE 7.—NET CHARGES FOR CONSTRUCTION AND MAINTENANCE OF PITCH-MACADAM ON PARK HEIGHTS AVENUE.

Section.	Width, in feet.	Pitching (first cost) per square yard.	Maintenance of Macadam, per Square Yard.					Yearly interest (6%) on first cost.	Yearly cost. (Average).	Average of traffic census, Maryland units.	Average yearly cost (per square yard) per traffic unit per foot of width, in mills.
			1910	1911	1912	Total.	Average per year.				
1	24 to 35	$0.327	$0.088	$0.9011	$0.0036	$0.9927	(a)	......	......	......	......
2	24	0.434	0.080	0.0000	0.0959	0.1759	$0.0586	$0.0260	$0.0846	(b) 15 000	0.135
3	24	0.418	0.187	0.9947	0.0044	1.1861	(a)	......	......	......	......
4	24	0.449	0.081	0.0000	0.0031	0.0841	0.0280	0.0269	0.0549	9 600	0.137
5	24	0.344	0.081	0.0457	0.0034	0.1301	0.0434	0.0206	0.0640	9 600	0.160
6	24	0.606	0.079	0.0563	0.0434	0.1787	0.0596	0.0364	0.0960	7 200	0.320
7	24	0.618	0.082	0.0214	0.0135	0.1169	0.0390	0.0371	0.0761		0.254
8	24	0.605	0.080	0.0098	0.0583	0.1481	0.0494	0.0363	0.0857		0.286
9	24	0.454	0.091	0.0049	0.0171	0.1130	0.0377	0.0272	0.0649		0.216
10	24	0.242	.....	0.0080	0.0052	0.0132	0.0666	0.0145	0.0211		0.070
11	24	0.264	.....	0.0042	0.0039	0.0081	0.0041	0.0158	0.0199		0.066
11-A	24	0.262	.....	0.0298	0.0100	0.0398	0.0199	0.0157	0.0356	4 800	0.178
12	24	0.327	.....	0.0349	0.0005	0.0354	0.0177	0.0196	0.0373		0.187
13	24	0.325	.....	0.0101	0.0005	0.0106	0.0053	0.0195	0.0248		0.124
14	24	0.292	.....	0.0118	0.0215	0.0333	0.0167	0.0175	0.0342		0.171
15	18	0.084	.....	0.0335	0.0157	0.0492	0.0246	0.0050	0.0296	(b) 3 114	0.171
16	18	0.140	.....	0.0980	0.0243	0.1223	0.0612	0.0084	0.0696		0.402
17	12	0.325	.....	0.0161	0.0143	0.0304	0.0152	0.0195	0.0347	2 400	0.174
18	12	0.287	.....	0.0343	0.0072	0.0415	0.0208	0.0172	0.0380		0.190
19	14	0.470	0.087	0.2663	0.0649	0.4182	0.1394	0.0282	0.1676	2 100	1.117
20	14	0.408	0.088	0.0845	0.0000	0.1725	0.0575	0.0245	0.0820		0.547
21	14	0.551	0.088	0.1805	0.0239	0.2924	0.0975	0.0331	0.1306		0.871
22	14	0.405	0.082	0.1851	0.0670	0.3341	0.1114	0.0243	0.1357		0.905
23	14	0.691	0.082	0.0756	0.0062	0.1638	0.0546	0.0415	0.0961		0.641
24	14	0.257	0.081	0.0555	0.0088	0.1453	0.0484	0.0154	0.0638		0.425
25	14	0.353	0.057	0.0763	0.0000	0.1333	0.0444	0.0212	0.0656		0.437
26	14	0.303	0.057	0.0286	0.0024	0.0880	0.0293	0.0182	0.0475		0.317
27	14	0.227	0.057	0.0056	0.0020	0.0646	0.0215	0.0136	0.0351	(b) 2 030	0.242
28	14	0.355	.....	0.0092	0.0442	0.0534	0.0267	0.0213	0.0480	(b) 336	2.000
29	12	0.074	.....	0.0308	0.0874	0.1182	0.0591	0.0044	0.0635		2.645

(a) Omitted from further consideration at this time because of recent construction. (b) From records; other units, approximations.

(*p*) For pitch-macadam, a pitch, to be satisfactory, should possess at least the following characteristics: Mr. Crosby.

(1) It should flow freely, though not excessively so, under the conditions of application.
(2) It should show, after evaporation at 105° cent. for 21 hours (20 grams in 3½-in. dish), a penetration of not less than 10 at 4° cent., and not more than 100 at 25° cent. (No. 2 needle, 100 grams, 5 sec.).
(3) The naphtha-soluble portions of the pitch, when evaporated on glass, should show themselves to be decidedly adhesive.

(*q*) In the cases of tar-pitches or pitch compounds, and for the purpose of lessening their susceptibility to temperature changes occurring after use, it is desirable that "free carbon" (matter insoluble in carbon bisulphide) be present to an extent greater than a minimum percentage of the fractional distillate from such pitches between 225 and 300° cent.; but, in order to avoid excessive hardness at low temperatures, this percentage of "free carbon" should be less than a maximum—the minimum and maximum referred to being largely dependent, for their expression in figures, on the local conditions.

(*r*) A 12-ft. width for the road metal is not economical where the travel aggregates more than 400 units per average day of 10 hours; nor is the 14-ft. width economical where the travel exceeds 2 000 units and the proportion of motor travel is more than 80% of the total.

(*s*) Where high-speed motor travel forms a large proportion of the total, the unit width of travel lines should be considered as 9 or 10 ft., instead of 7 or 8 ft., as heretofore, because of the greater clearance required for the safe passing of the units of such travel.

Further economic conclusions seem to be rather premature at this time, and such, including a deduction concerning the possible advantage of using an excess of pitch during construction in order to prolong the life of the pitch-macadam, and perhaps in the end to reduce the cost, it would seem preferable to defer for two or three years.

GEORGE W. TILLSON, M. AM. SOC. C. E.—In these days of increase in the values of labor and materials, and the prospect that they will continue to increase, it certainly is incumbent on those who utilize these two elements to know that it is done to the best advantage, to see that when they are combined and produce a result, that the result has not cost more than it should. It is not enough for a contractor to know whether a job is a paying one, or a losing one; he should know whether or not every part of his contract is being carried out on a paying basis. Mr. Tillson.

It seems to the speaker that, as Mr. Lewis has said, a great deal of the work which has been done on cost records and reports is more in

Mr. Tillson. the nature of accounting than of cost-keeping. Construction work is not done for the purpose of allowing some one to get up an elaborate system of accounting, strange as it may seem to some accountants. The cost-keeping, or the accounting, should be carried on in such a way as to give detailed information about the work, and the important point is to analyze the situation properly into its different elements. By an analysis a contractor can determine very quickly whether a contract is or is not a paying one, if properly carried out. After he does that, he can establish a system of costs for the different movements in carrying out the work. In keeping account of the cost of items, it is possible to go too far; it is possible to build such an elaborate system of cost-keeping that no general result is obtained.

In the Bureau of Highways, in the Borough of Brooklyn, a very good system has been in use for several years, by which it is possible to show the cost of every item in connection with the work in that Bureau. The following from the report of the Bureau for 1911 shows the system of cost-keeping used for the repairs of asphalt pavements, and how the same has been analyzed and subdivided into different items:

ANALYSIS OF MAINTENANCE COSTS.

General and Special Costs.	Wearing Surface. Per Box. (9.3 cu. ft.)	
Superintendence	$0.056	
Superintendent's auto	0.051	
Repairs to plant	0.128	
Repairs to tools	0.108	
Dumping privilege	0.094	
Coal	0.092	
Wood	0.046	
Misc. supplies, etc.	0.052	
Depreciation	0.095	
Interest	0.047	
Rent	0.033	
		$0.802
Material Costs.		
Asphalt	$1.220	
Residuum oil	0.033	
Stone dust	0.195	
Asphalt sand	0.208	
		1.656
Labor and Trucking Costs.		
Plant labor	$0.423	
Street labor	1.694	
Trucking	0.556	
		2.673
Total		$5.131
Cost per cubic foot		$0.552

The total for the 9.3 cu. ft. of material is \$5.13$\frac{1}{10}$ or 55$\frac{2}{10}$ cents per cu. ft. It takes about 1.75 cu. ft. for 1 sq. yd. of asphalt 2 in. thick. If the contractor has his work divided on some such principle as that, he can tell absolutely what each item has cost. By daily reports as to the quantity of work done by his different gangs in different parts of the city, he is able every morning to tell whether each man is coming up to his idea of what he should do, or what the records of previous years had shown that men and teams could do. Mr. Tillson.

WILLIAM H. CONNELL, ASSOC. M. AM. SOC. C. E.—If engineers wish to keep abreast of the times and attain the highest point of efficiency in their work, cost records and reports are essential. Mr. Connell.

The moral effect alone on an organization is justification for keeping unit cost records. This is illustrated by the pride aroused in the men in connection with their work. The natural instinct of man is to excel in his undertakings, but it must be remembered that men must be led and not driven, and in order to get the best out of them their interest in their work must be aroused, and they must be impressed with a sense of their responsibility. There is no better way of doing this than by the friendly competition resulting from unit cost records. Men are naturally ambitious—this is clearly illustrated in pastimes and sports, whether it be shooting marbles, pitching quoits, playing baseball, or any other form of amusement that brings out competition—all want to excel, and will work hard to do so; one reason is because they understand what they are doing and are interested; the other is because their ambition is aroused through competition, with the result that they will do the best they can. This same situation should exist in all classes of work. There is no man—no matter how lowly he may be, or whatever may be the nature of his work—whose interest cannot be aroused by impressing him with a sense of his responsibility and showing him wherein the competition lies in connection with his work. Men are often lackadaisical about their work because they do not understand just what part they are playing, and, consequently, have no particular interest in it, whereas if they understood more about the relationship of their work to the undertaking as a whole, their interest would be aroused and they would appreciate their responsibility. The only difference between amusements and work, in bringing out competition, is that in the first instance the man understands the game, has a part in it, and plays it for all it is worth; while in the latter instance he does not understand the work or his part in it; consequently, his interest is not aroused and he does not put forth his greatest efforts, which is not only a loss to him, but to his employers. Therefore, anything that can be done to arouse the interest of the men in their work and bring about friendly competition is of inestimable value, and nothing will do more to produce this result than unit cost records.

Mr. Connell. Cost records are probably the principal means of control of work, and unit cost records are an analysis of cost records, and bring out the weak and strong spots in a working organization. As already stated, unit cost records are simply a modern system of records designed to keep the work and organization up to the highest point of efficiency. Such records are also of great value in comparing costs of similar work in different industrial establishments, municipalities, public works departments, etc. It has often been said that unit cost records do not mean anything on account of the different conditions under which work is done, the difference in wages, labor hours, etc. Of course they are of no value, and are only misleading, unless they are given in detail, but if this is done, and if they are properly compiled, such records are comparable with cost records of similar work in other establishments and localities, and are invaluable. Only a few months ago, the budget for the Highway Bureau of Philadelphia, Pa., for 1913, was made up largely by proportioning the unit cost of similar work in the Borough of The Bronx, New York City. This was made necessary by the absolute lack of cost records or reliable data of any description in connection with the work coming under the jurisdiction of the Bureau. It is impossible to make up an intelligent estimate without the aid of cost records, and it is equally impossible to determine whether all branches of the work are being carried on in an economical manner in the absence of unit cost records.

There seems to be a rather general impression that the necessary job orders, time sheets, material reports, and progress reports which the foreman is required to handle, are apt to confuse him and, consequently, decrease rather than increase the efficiency of his work. This is not so; on the contrary, they tend to develop the foreman, awaken his interest, and, in many instances, make a new man of him. Why? Simply because he is placed on his mettle, taken in, to a certain extent, on the financial and business end, made a more important factor in the organization, and, consequently, his work means more to him than the mere physical results. We underestimate the ability of the working classes. A large majority of them, of course, have not had the advantages of an education, but they are all capable of being developed, and are simply waiting for opportunities. Just because a foreman never made up modern cost record reports is no reason why he cannot do it; naturally, it would be confusing in the beginning, and he would make a great many mistakes, but before long, in all probability, he would be suggesting improvements in the form of the reports, which would be better suited to the conditions.

Cost records and reports are invaluable guides in the conduct of work of whatever nature, and must not be underestimated if engineers wish to carry on their work in an efficient and economical manner.

A. H. BLANCHARD, M. AM. SOC. C. E.—Labor is an element of road costs which demands careful consideration. Many instances may be cited where equally competent engineering supervision governed work of the same character and where the costs of materials were the same, but where the quality of labor and the number of working hours were not equivalent, and hence the total prices varied to a remarkable extent. The speaker has been connected with work where the hours were the same but, due to incompetency on one hand and ability on the other, the unit labor cost in the former was three times that in the latter case. It is evident that complete data relative to labor should be given, otherwise erroneous deductions will be made. Mr. Blanchard.

In connection with construction and maintenance work accomplished under the day-labor system in State, county, and municipal departments, many labor costs are given. Here, without doubt, one finds the greatest variation in the quality of the labor. Poor administration, and political interference with the personnel of the labor organization, are mainly accountable for the marked difference in quality which exists.

H. W. DURHAM, M. AM. SOC. C. E.—One essential feature in regard to cost records is the importance of not letting the keeping of such records become the end instead of the means; undue emphasis should not be placed on the machinery of cost-keeping. Frequently, the matter of recording becomes so laborious, the organization doing it so great, that it is really regarded as the ultimate end to be sought, and, by the time the tabulations are made and the costs worked up, the information obtained is of no particular value on the immediate work. Mr. Durham.

For efficiency, cost records must be kept so that the results can be compiled at short intervals of time, and give some comparison as to the items of the work immediately under consideration, in order that it can be seen instantly whether or not the work is going on properly. It should also be borne in mind that detailed cost records may not be of such great value to the engineer supervising contract work as they would be were he directly handling by day's labor an organization and could point out to the individual gangs where one excelled another.

For a city or municipal organization, there are no better general methods than those which have been adopted by the Board of Water Supply of New York City, the Public Service Commission, and similar organizations.

Details as to how the records should be kept, what charges should be made, overhead plant charges, etc., are matters which concern all engineers. It is not only necessary to know the price of the materials that are being actually used, but what is being paid for labor and other items, the charge for depreciation on plant, overhead charges, and matters of like character.

Mr. Durham.

Unless such correct distribution of the details of cost is made, the records become worse than useless and allow wrong inferences to be drawn, as in a case of certain road work with which the speaker is familiar, where an excessive unit cost per mile, when analyzed, was shown to be largely due to the inclusion of the entire first cost of the plant used.

Mr. Wilcock.

FREDERICK WILCOCK, ASSOC. M. AM. SOC. C. E.—Determination of engineering costs is important in the public service. Such costs, if compared periodically with the contractors' requisitions for payment for work done, and published for the engineers, are an inducement to eliminate the inefficient members of the corps as soon as possible, and tend to improve the standards of the younger members of the Profession. The elimination is made usually at the end of the probationary period customarily required by civil service rules. This opinion is drawn from observation of construction work in New York City.

DESIGN OF HIGHWAY SYSTEMS.

Mr. Pulligny.

JEAN DE PULLIGNY, M. AM. SOC. C. E.* (by letter).—The writer will not undertake to decide what a highway system ought to be, but will outline briefly what the French highway system is, in the belief that such a system, with appropriate modifications, might furnish a basis for an American centralized State system of highways.

THE FRENCH ROAD SYSTEM.

The following remarks do not apply primarily to the National Main Highways which connect Paris with the large cities and the frontiers, and are constructed and maintained by the Central Government. These main highways (*Routes Nationales*), were built more than 150 years ago—when scarcely any roads were to be found in other countries—for carrying the Royal mail.

Their total length is about 24 000 miles, and the annual appropriation for their reconstruction and maintenance is $6 500 000. The total width of these main highways is 43 ft. 4 in., 53 ft. 4 in., or 81 ft. 3 in., according to classes, including lateral ditches of 6 ft. 8 in. and a central metaled roadway of 16 ft. 8 in., 20 ft., or 25 ft. 6 in., generally constructed of water-bound macadam which is tarred or oiled in summer. On the sides of most of these roads trees are planted, and form graceful avenues, of which many are old and quite beautiful.

The cost of building and maintaining these roads is rather high. It varies, of course, in different parts of France, and, in the past, it has varied according to the times. The general expense for the 24 000

* Most of the information in this discussion has been collected expressly for American engineers by the noted road expert, M. Le Gavrian, of Versailles, *Ingenieur des Ponts et Chaussées;* and Assistant General Secretary of the Permanent International Association of Road Congresses.

miles of main roads has been about \$300 000 000, or an average of \$12 600 per mile. The cost of maintenance is about \$6 500 000 yearly, averaging \$270 per mile. If the average highway of this kind is considered as being about 20 yd. wide, including ditches, the prices per square yard would be \$0.35 for construction and \$0.00765 for maintenance. If the width is taken at only 15½ yd., the ditches excluded, the maintenance cost would be about \$0.0099 per sq. yd. Mr. Pulligny.

These highways played a very important part in National activity in France, before railroads were constructed. Nowadays, it is believed by the writer, they are less important than the other roads of the country, which amount to 339 500 miles in length and require an annual expenditure of \$37 400 000. These roads include mainly *Chemins Vicinaux de Grande Communication*, connecting the cities and villages, and the less important *Chemins Vicinaux Ordinaires*, which connect farms with the next village or the nearest city.

The total widths of the *Chemins de Grande Communication* are 23 ft. 4 in., 26 ft. 8 in., 33 ft. 4 in., or 43 ft. 4 in., according to the class. These widths include lateral ditches of 3 ft. 4 in. or 5 ft., and a central metaled roadway of 13 ft. 4 in. or 16 ft. 8 in. In the case of the simple *Chemins Ordinaires*, the total width is 20 ft. with ditches of 3 ft. 4 in., and a central roadway of only 10 ft. As to the *Chemins Ruraux*, their dimensions may be still less, and sometimes there are no ditches.

On the National highways the maximum grade is 3 in 100, and the minimum radius of curves is 150 ft. On the other roads the maximum grade is 5 in 100, and the minimum radius of curves is 100 ft. It is important not to increase these grades. On a 3 in 100 grade the effort in hauling a load is about twice as much as that required on a good level road, and on a 5 in 100 grade, the effort is nearly tripled. If the length of such an incline is short, the horses may give the needed supplementary effort, and no reduction of the load is necessary; but if the slope is steep for a long distance, such a reduction is unavoidable. As it applies to the total load, and as the dead load cannot be reduced, it is understood that the useful load is reduced proportionally. Motor trucks are affected as much as horses in such cases, and perhaps more.

Before returning to the subject of main highways, the opinion is expressed that some system of Federal or State main highways, built and maintained by Federal or State engineers, may certainly be justified in the United States, where there is no lack of able engineers, centralized authority, or money. The difficulty is to provide the other system of ordinary roads with able engineers, with centralized authority, and with sufficient yearly appropriations. It is this phase of the subject which will be further considered.

Mr. Pulligny.

Technical Organization of the French Road System.

France is not so strictly centralized as it is believed to be by many engineers. It is divided into 86 territorial units, called *Departements,* the average area of each of which would be about equal to 3 counties of the State of New York. Hence, New York, having 61 counties, would make 20 French *Departements.* The 86 *Departements* (plus Belfort Territory) are divided into 275 *Arrondissements* (average by *Departement,* $\frac{275}{86} = 3.2$). The 275 *Arrondissements* are divided into 2 325 *Cantons* (average by *Departement,* $\frac{2\,325}{86} = 27$; average by *Arrondissement,* $\frac{2\,325}{275} = 8.4$); and the 2 325 *Cantons* are divided into 36 222 *Communes* (average by *Departement,* $\frac{36\,222}{86} = 420$). The gross area of France is 207 000 sq. miles. The average area of an *Arrondissement*, therefore, is $\frac{207\,000}{275} = 750$ sq. miles, being about the average area of a New York county. The area of New York State is 49 204 sq. miles, and the average area of each county is $\frac{49\,204}{61} = 800$ sq. miles.

Each Department is also a unit for several public services, and, furthermore, is a political unit. It has a Governor, appointed by the Central Government, called a *Prefet,* and an elective body called the *Conseil Général.* It has also certain revenues produced by taxes, the appropriation of which is decided by the *Conseil Général.*

All the road system of *Chemins Vicinaux* is managed by the *Prefet,* and the expenditure is voted by the *Conseil Général,* the Central Government having practically nothing to do with it.

The *Prefet,* of course, does not manage the road system himself, but through a centralized body of competent technical men. In about half the Departments the work has been entrusted by the *Conseils Généraux* to the body of Government Engineers—*Ingenieurs des Ponts et Chaussées*—to which the writer has the honor to belong. These roads comprise only a small part of their work. They also have in charge the National Main Highways and the various civil engineering works which are administered by the French Government, including all the inland navigation works, canals and canalized rivers, all the ports, docks, harbors, sea shores, and light-houses, and the close inspection maintained by the French Government over the railroads, with reference to safety, regularity, and rates, and also to secure a proper maintenance of the railroad property which is only entrusted to the railroad companies for a definite period, at the expiration of which, such property will be returned to the Government.

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In the other half of the Departments (exactly forty-six) special technical bodies have been organized, which are, of course, quite outside of politics. They include a chief road engineer, residing at the Capital of the Department, near the *Prefet*, and having charge of all the *Chemins Vicinaux* of the *Departement*.

Each *Departement* is divided into three or four political districts headed by a *Sous Prefet*, and called an *Arrondissement*. In each Capital of each district there resides a district road engineer who is under the orders of the chief road engineer and has charge of all the *Chemins Vicinaux* of the *Arrondissement*.

Each *Arrondissement* is divided into eight or nine judicial districts, named *Cantons*, each of which also has its small Capital, in which resides an assistant road engineer who has charge of all *Chemins Vicinaux* included in the *Canton*. He is under the orders of the district road engineer.

Finally, all roads in a *Canton* are divided into sections, each having an average length of 4 miles, and on each of these sections the celebrated French *Cantonnier*, or road patrolman, works constantly with his pick-axe, shovel, shrub, and wheel-barrow. These *Cantonniers* are under the orders of the assistant road engineer. A few of them have a shorter section, and they look after the work of their neighbors, as foremen (*Chefs Cantonniers*). The Cantonniers are simple laborers, generally of agricultural training, and are not required to have any special knowledge in order to enter the service. They are only expected to be of respectable behavior, to be able to read and write, and to be steady and trustworthy workers.

It is evident that every square yard of French roads is under the permanent care of a patrolman, of a chief patrolman, of an assistant road engineer, of a district road engineer, and of a chief road engineer. All these men form a hierarchy, with the *Prefet* as the head. Any complaint by the people, or their representatives, to the *Prefet* is properly attended to.

All members of the road service, from the patrolman to the chief engineer, work under a civil service law. When they have once entered the service, they can only be dismissed in case of serious misbehavior. They are promoted at regular intervals, with better pay, and when they retire, after thirty years' work, they get an old age pension.

Most of the patrolmen lack sufficient knowledge to become assistant engineers. The latter are recruited by public competitive examinations, taking place every two or three years, from among young men who have studied, by themselves or in school, the necessary subjects such as the elements of mathematics, surveying, drafting, designing, and road construction and maintenance. The boys employed as helpers for drafting, designing, and surveying, in the offices of road engineers, also generally undergo these public examinations. Their practical experience serves

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them well, and most of them succeed. The district engineers are generally chosen from among the most able and experienced of the assistant engineers who have had many years of service. The chief engineer for the whole Department may have been previously a district engineer, but it is not obligatory. In some cases he was formerly a civil engineer, a graduate from one of the principal schools, an architect, or an *Ingenieur des Ponts et Chaussées.*

Table 1 shows the number of chief, district, and assistant road engineers in each of the 46 Departments where a special road service has been organized.

TABLE 1.—NUMBER OF ENGINEERS, ETC., ON FRENCH ROADS IN DEPARTMENTS HAVING A SPECIAL ROAD SERVICE.

Departments.	Chief Road Engineers.	District Road Engineers.	Assistant Road Engineers.	Field and Office Graduate Assistants.
Ain	1	5	41	46
Aisne	1	6	55	7
Hautes Alpes	1	4	22	8
Ardennes	1	5	32	6
Ariège	1	4	22	11
Aude	1	4	49	16
Calvados	1	6	34	26
Cher	1	2	21	9
Corrèze	1	2	33	7
Creuse	1	4	27	3
Dordogne	1	5	42	21
Doubs	1	5	26	11
Eure	1	7	44	12
Gard	1	4	36	10
Haute Garonne	1	5	48	16
Gironde	1	10	48	48
Hérault	1	5	49	15
Ille-et-Vilaine	1	7	37	16
Indre-et-Loire	1	3	25	15
Isère	1	7	52	30
Jura	1	5	36	10
Landes	1	4	25	9
Lozère	1	2	19	12
Manche	1	6	51	14
Haute Marne	1	4	33	3
Meuse	1	4	39	14
Morbihan	1	6	25	10
Nièvre	1	3	30	9
Nord	1	8	53	28
Orne	1	5	36	15
Puy-de-Dôme	1	5	53	..
Pyrénées-Orientales	1	2	25	6
Haut Rhin	1	..	5	3
Rhône	1	3	32	29
Haute Saône	1	3	34	4
Sarthe	1	5	34	13
Seine-et-Oise	1	7	51	17
Seine-Inférieure	1	5	50	29
Deux Sèvres	1	4	31	12
Somme	1	6	45	15
Tarn	1	5	28	18
Tarn-et-Garonne	1	2	20	13
Vendée	1	8	26	6
Vienne	1	6	32	15
Vosges	1	6	34	6
Yonne	1	6	42	6

As examples, statements will be given concerning the salaries of the road engineers and assistants in two Departments: In Seine-et-Marne (population = 358 325; area = 2 300 sq. miles) the service is entrusted to the *Ingenieurs des Ponts et Chaussées*: in Seine-et-Oise (population = 707 325; area = 2 170 sq. miles) there is a special service of departmental road engineers. Mr. Pulligny.

DEPARTMENT OF SEINE-ET-MARNE.

(Road Service Entrusted to the Government Civil Engineers.)

The body of Government Civil Engineers (*Ponts et Chaussées*) was created on February 1st, 1716, and the *École des Ponts et Chaussées*, for the education of such engineers, was founded in 1750.

The classes and salaries in the body of the *Ponts et Chaussées* are as follows:

	Annual salary.	
Inspecteur Général	$2 900 to $3 400,	according to seniority.
Ingénieur en Chef	1 900 to 2 300	" " "
Ingénieur Ordinaire	965 to 1 350	" " "

In addition to their Government work, these engineers are allowed to work for departments, cities, chambers of commerce, etc. From this and from other supplements given by the State itself nearly all engineers earn at least $200 yearly. Many earn more, and the supplements of a few equal or exceed their State salary.

The State salaries of their assistants are as follows:

Conducteurs (Assistant Engineers), $425 to $965 per annum, according to seniority.

Commis (Office and Field Graduate Assistants), $280 to $675 per annum, according to seniority.

After 30 years of employment, all engineers and assistants are granted an old age pension of about one-half of the highest salary they have obtained. Besides their State salary and supplements, the engineers and their assistants receive the following fees for their departmental road service:

		Annual fee.
Ponts et Chaussées:	Chief Engineer	$1 150
	District Engineer	575

Conducteurs (Assistant Engineers)	$123 to $192,	according to seniority.
Office Assistants: Head clerks	210 to 385	" " "
Typewriters and field and office assistants	50 to 150	" " "

The patrolmen are special for the Departmental Road Service. Their monthly salary is as follows, according to seniority:

Chief Patrolman	$25 to $27
Patrolman	19 to 21

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When these officials are ordered to travel outside the limits of the city in which they reside, they receive traveling expenses.

During 1912 the total salaries, traveling, and sundry expenses for the road officials, including patrolmen, in the Department of Seine-et-Marne, amounted to $28 000.

Department of Seine-et-Oise.

(Special Departmental Road Service.)

The salaries and old age pensions after 30 years' service are as follows:

	Annual salary.			Annual pension after 30 years' service.
Agent Voyer en Chef (Chief Road Engineer			$1 920	$1 440
District Engineer	$960	to	1 100	825
Assistant Engineer	480	to	850	640
Office and Field Graduate Assistants	280	to	575	430
	Monthly salary.			
Chief Patrolman	$22	to	$25	121
Patrolman	16.50	to	19	100

Many employees also receive various supplements for the high cost of living in certain cities, help to large families, extra work, traveling expenses, etc.

The total of these expenses for the office staff in the Department during 1911 was $10 400. The total expense for patrolmen and chief patrolmen, including all sundry expenses, was $72 500.

These two Departments are near Paris, where the cost of living and all salaries are high. In many other Departments, the salaries would be smaller by 10 and, in a few, by 25 per cent.

The total expense for the *Chemins Vicinaux* of all classes during 1910 amounted to $37 500 000, as follows:

Regular maintenance	$26 355 000
General repairs	2 100 000
Building new roads	4 420 000
Land acquisitions	890 000
Sundry expenses	335 000
Salaries and general expenses	3 400 000
Total	$37 500 000

Administrative and Financial Organization of the French Road System.

The engineers of the road service not only build new roads and maintain existing ones, but take an important part in the administrative and financial working of the road system.

The assistant engineers walk nearly all day on the roads of their district, or they may ride on a bicycle, in a carriage, or in an automobile. They constantly meet the elected Mayors of the small towns, and they know all the needs of the people. Knowing also approximately the available resources for the coming year, they prepare, for each township and for each road of their district, a scheme for maintenance expenses and for the building of new roads. They send their reports to the district engineer who sums them up and makes any changes he deems necessary. Mr. Pulligny.

All the district engineers forward their reports to the chief engineer who designs a general scheme for the maintenance and building of new roads in the whole Department. Each town or village has its small elective body which is called to deliberate on the road work and on the expense in which it is concerned. A Bill for this scheme is then discussed by the Department's Legislature in its annual session, and may undergo some changes. The appropriation is finally voted, and the works are then carried out with no more intervention on the part of the political representatives, the road engineers acting only under the authority of the *Prefet*. The expense is levied on the town or village as a public tax, even if the people do not approve of it.

The *Chemins Vicinaux*, thus taken care of by the Department, are the *Chemins de Grande Communication* which connect two or more towns or villages. In such cases it is admitted that the maintenance of the roads must not be entrusted to the townships, because one town might do its share of the work and suffer because the other town would not do the same; therefore, the money is provided by the town taxes, but the direction of the work is assured by the Department.

The construction of new *Chemins de Grande Communication* is undertaken by the Department for the same reason, but, in this case, there is an important difference as to the origin of the funds. Instead of providing all the money from municipal revenues, the towns only give a part of it, and the remainder is appropriated by the Department from its share of certain taxes, the amount of which is divided between the Central State, the Department, and the towns. The sharing of the expense between the town and the Department is provided in accord with definite rules, in which both the needs of the township and its resources are considered.

The total revenue produced by certain taxes is supposed to be an index of the comparative wealth of the townships, and the area of their district is considered as a measure of their needs for roads. The revenue being divided by the area, the quotient is considered as an index number by which the townships are classified, and, for a certain index number, they may receive a definite percentage of help from the Department, as high as 85% for a very poor township with a very wide area needing very long roads.

Mr. Pulligny. A similar classification is made in the Departments on the same double basis of wealth and area, and an annual appropriation from the Central Government's fund is divided between the Departments as a National aid for the construction of their roads. This appropriation amounted to only $2 000 000 in 1910. It has been larger in certain other years.

Such is the technical, administrative, and financial system, and it has worked satisfactorily in France for nearly a century. It only applies to the *Chemins Vicinaux de Grande Communication* which concern two or more towns or villages.

As for the *Chemins Vicinaux Ordinaires, Chemins Ruraux,* and *Rues* (streets) which concern only one town or village, the Mayors are free to build and maintain these roads out of the municipal funds, as they wish. In fact, all the villages and small towns voluntarily entrust their road work to the assistant road engineer whom they see daily, and he does it for a small fee. If a town is more important, if it has a few municipal works of sewerage, water, gas, or electricity, to be looked after besides the road work, a special engineer is appointed and takes care of the whole. If a city is still more important, one or more municipal engineering services are organized. The municipal engineering services of the City of Paris are extremely complete, and their organization is most remarkable, from every point of view.

A few words may be devoted to two other divisions made by the the laws of the past in reference to the French roads, namely, the *Routes Departementales* and the *Chemins d'Interet Commun,* which are nothing more than types of *Chemins de Grande Communication.*

The difference in names carries a few changes in the rules governing the management of these roads and the corresponding funds. These changes are not directed toward simplicity. For many years the tendency in all Departments has been to have only one class of roads, the *Chemins de Grande Communication.* No more *Chemins d'Interet Commun* are created, and every year some *Routes Departementales* are dropped from the official lists, and are afterward considered as *Chemins de Grande Communication.* The length of the *Routes Departementales* has decreased from 29 500 miles, in 1869, to 8 100 at the present time.

On January 1st, 1911, the 395 729 miles of *Chemins Vicinaux* were distributed as shown in Table 2.

As previously stated, there are also 8 100 miles of *Routes Departementales* and 24 000 miles of *Routes Nationales,* forming a grand total of 428 000 miles of roads of all classes.

The building and maintenance expenses of the *Chemins Vicinaux* have varied according to time and place, but the figures in Table 3 give an idea of what they usually cost. The lengths considered include only the roads accepted or under construction.

TABLE 2.—CHEMINS VICINAUX.

Mr. Pulligny.

Condition.	DE GRANDE COMMUNICATION.	D'INTERET COMMUN.	ORDINAIRES.	TOTALS.
	Miles.	Miles.	Miles.	Miles.
Accepted and regularly maintained	107 000	47 200	178 000	332 200
Under construction	287	302	6 700	7 289
Only designed	970	1 770	53 500	56 240
Total	108 257	49 272	238 200	395 729

TABLE 3.—USUAL COST OF FRENCH ROADS.

Classes.	Total length, in miles.	AVERAGE WIDTH, IN YARDS.		APPROXIMATE COST OF:					
				Building.			Annual Maintenance.		
		Ditches included.	Ditches excluded.	Total expense.	Per mile.	Per square yard, ditches included.	Total expense.	Per mile.	Per square yard, ditches excluded.
Routes Nationales	23 800	20	15½	$300 000 000	$12 600	$0.36	$6 500 000	$270	$0.0099
Routes Departementales	8 100	14	11	63 000 000	7 750	0.32	1 500 000	185	0.0095
Chemins Vicinaux de Grande Communication	107 300	10¾	8½	665 000 000	6 200	0.33	16 900 000	157	0.0105
D'Interet Commun	47 500	10	7½	178 000 000	3 750	0.21	6 000 000	126	0.0095
Ordinaires	184 700	9	6½	457 000 000	2 470	0.16	14 500 000	78	0.0068
Totals	371 700	....	....	$1 663 000 000	....	....	$45 400 000	....	......

For comparison the figures relating to the *Routes Nationales* have been reproduced, and also some for the *Routes Departementales*.

The total length of French roads is nearly 372 000 miles, and their total cost may be considered roughly as more than $1 500 000 000. The difference between these 372 000 miles and the total of 428 000 previously given, results from the omission from Table 3 of the 56 240 miles which have only been designed. There are also about 155 000 miles of farm roads, with or without ditches, metaled roadway, and maintenance.

The annual maintenance of the 372 000 miles of regular roads requires nearly $45 500 000, the share of the Central Government being $6 500 000 and that of the 86 *Departements* nearly $39 000 000. This shows a contribution of about $1 per head of population.

Mr. Pulligny. For comparison, a few rough figures are given in Table 4 in regard to the other means of public transportation in France, long-distance railroads, local railroads, road cars, canalized rivers, and canals.

TABLE 4.—LENGTH, COST, ETC., OF FRENCH RAILROADS, TRAMWAYS, CANALIZED RIVERS, AND CANALS.

	Total building expense.	Total length, in miles.	AVERAGE COST:		
			Building per mile.	Annual Maintenance.	
				Total.	Per mile.
Long-distance railroads...	$3 100 000 000	25 000	$124 000	$31 000 000	$1 240
Local railroads............	370 000 000	5 200	71 000	1 610 000	310
Tramways (road cars)....		5 750			
Canalized rivers...........	81 000 000	4 350	18 600	1 160 000	266
Canals......................	161 000 000	3 100	52 500	960 000	310
Grand totals.........	....	43 400	....	$34 730 000	....

The total length operated, the total freight, in American tons per mile, and the total revenue of railroads, are given in Table 5.

TABLE 5.—LENGTH, TRAVELERS, FREIGHT, REVENUE, ETC., ON FRENCH RAILROADS, CANALS, ROADS, ETC.

Railroads, Canals, etc.	Length operated, in miles.	Number of travelers at one mile, in millions.	Freight, in millions of ton-miles.	Gross operating revenue.	NET OPERATING REVENUE.	
					Total.	Per mile.
Long-distance railroads (1908)........	25 000	9 900	14 100	$330 000 000	$140 000 000	$5 650
Local railroads (1907).................	4 730	235	105	6 800 000	1 500 000	325
Tramways (road cars) (1907)..........	3 130	157	30	3 700 000	500 000	159
Canalized rivers.......................	4 350	....	1 940	....	....	......
Canals..................................	3 100	....	2 000	....	....	......
National roads..........................	24 100	....	1 880	....	....	......
Departmental and vicinal roads......	347 600	....	1 880			

Mr. Brewer. BERTRAM BREWER, M. AM. SOC. C. E.—In Massachusetts there are Boards of Survey which, to a certain extent, may control the development of the roads in any municipality. Every town has the privilege of accepting a State law which provides for such a Board, and, in many cases, the cities, to which this general law does not apply, have secured from the Legislature a special act governing their own particular cases. These laws vary somewhat, but they are all framed with one end in view, namely, the creation of a board which may guide and, as far as is legally possible, control the design of the various municipal highways or systems of highways.

Mr. Brewer.

In the City of Waltham these highways are classed as main thoroughfares or interurban roads, local thoroughfares or parkways, and, thirdly, residential streets. It is the duty of the Local Board to record plans, either by adopting the petitioner's designs or by making its own, which will secure a system of highways to fit the peculiar needs of the place. Much can be, and has been, done toward the improvement of municipal street systems. It is a fair question, however, as to whether or not great systems of highways, either State or National, can be built up in this way, though local boards are often broader-minded than one would expect, especially if they are intelligently and tactfully advised by a competent engineer.

The speaker wants to make a plea for more consideration, on the part of engineers, for some of those things which cannot be determined altogether by the transit; a consideration of those factors which make for more permanent values, not only in the road itself, but in the abutting property; a consideration of the fact that, as Stevenson puts it, "every year, as a road goes on, more and more people are found to use it and others are raised up to repair and perpetuate it and keep it alive"; and, he might have added, "to build beside it".

Two factors which contribute to this permanency of values, not only to the road itself, but also to its surroundings, are often ignored, namely, adequate drainage and the development of suitable and attractive building sites. The engineer fails to remember that drainage of the road itself is no more essential than a location which will admit of inexpensive and adequate drainage of the whole territory which it serves. It is time also for him to remember that even the larger systems of highways will be built on sooner or later, and the character of the building sites which they are designed to develop and serve, on account of appropriate and attractive location, is becoming appreciated more and more by the people of the United States. Highways of any sort cannot be designed and engineered in the same way as a railroad system, for itself and its own particular uses alone. Its surroundings are as important as itself, and too often are entirely overlooked.

Mr. Lewis.

NELSON P. LEWIS, M. AM. SOC. C. E.—Highways are intended primarily to supply means of communication and transportation, to permit travel from place to place with a minimum of effort and resistance and in the least possible time. The importance of an intelligent and rational system of roads has not been appreciated. Much attention has been devoted to details of construction, and properly, but there has been too little regard for the real purpose of the highway. Much has been said and written about the planning of the streets of towns, but little about the design of the system of rural highways leading to and from towns and cities, and yet the difference is largely one of scale, rather than of principle. The considerations which should con-

Mr. Lewis. trol the development of a system of highways in city, county, or state, have been quite generally disregarded, the chief aim usually having been simply to afford access to the abutting plot, estate, or farm.

The first highways in the United States were developed in a very crude fashion. They followed lines of least resistance; the road surface was the natural soil; the grades were necessarily light, owing to the poor surface, and therefore the roads were circuitous. As the communities which these roads connected grew in population and importance, a better road surface was demanded, but little attention was given to the straightening of lines in order to furnish more direct routes. Little regard has been paid to the general appearance and attractiveness of highways between centers of population. In many cases the main connecting roads lead from some secondary or shabby street in one town or city to a street of the same class in another town; the impression which the user of the road gets of both towns is unfavorable, and the highway loses much in attractiveness and dignity. If such a connecting road approached and entered a town along well-designed roads and streets, increasing in importance and dignity until the civic center was reached, travel over them would be a pleasure as well as a mere attempt to get somewhere.

Every city and town has a straggling system of roads running out into the suburbs, which some day will become important streets, if not thoroughfares, but they are frequently allowed to remain straggling roads until the development of the abutting property has advanced so that a widening and straightening will involve an expense which is prohibitive. To advocate the improvement of such roads in anticipation of future growth requires courage, and will result in criticism from some quarters. To allow them to remain until necessity demands their improvement may be easy, but such a course cannot be justified.

Mr. Owen. JAMES OWEN, M. AM. SOC. C. E.—To appreciate the development of any of the systems of highways in the United States, the condition of the country must be considered. There are perhaps three or four methods of development: In the pioneer development, which took place during the Colonial era, when a man built a house distant from his neighbors, he built a road to it. He generally put his house on a hill. The road finally was extended into a main highway, and that is why a great many of the highways of the Eastern States are not properly located and are bad in grade and alignment; but they are fixtures. The developments along them preclude any main deviation from their original location. About 1820 the Government formulated the purpose of taking the Mississippi Valley and staking out the whole country in one section. The rule was to have a north and south road for each mile. The problems of direction and ease of access were ignored, and even the question of grade was not considered.

The great necessity of wagon travel to-day is through roads in every locality where there is a growing population. There is an utter lack of local appreciation of through highways. Mr. Owen.

AMOS SCHAEFFER, M. AM. SOC. C. E.—France has undoubtedly the best and most highly organized system of highways of any nation in the world. The systematic construction and maintenance of its public roads probably also dates back farther than that of any other country. The method by which the money is raised to construct and maintain the roads under the jurisdiction of the different authorities is indicated by their classification. Mr. Schaeffer.

Nearly every nation exercises more or less control over its highways, depending on their character and use. Where such control is exercised, the roads are usually divided into two or more classes which indicate whether they are main or secondary highways, and also largely under what governmental jurisdiction they are. This classification is very minutely carried out in France and represents the relative importance of the roads as arteries of traffic. In most other countries there are not more than two or three classes. Germany is perhaps the most important exception to this method of control. It has no control over its highways, except in Alsace-Lorraine.

In the United States, during the past decade, a great many States have appropriated funds and created organizations for the improvement of the public highways. As these improvements are made, roads pass from local to State control, and the speaker predicts that the time is near at hand when the Federal Government will also take an active part in highway construction. It is even now exerting a great influence by encouraging the improvement of roads in various ways, recommending road materials, superintending the construction of experimental roads, and distributing literature on the subject throughout the country. When the Federal Government does take an active part in road construction, the "Design of Highway Systems" will be on broader lines than has yet been attempted.

In these remarks the speaker will confine himself to the location of roads rather than to the design of the cross-section of the roadway, drainage, road materials, methods of construction, and various other matters which form more particularly a part of the details of the design of highways.

The agitation for better roads has an international scope. The problem of co-ordinating and relocating existing roads, locating new ones to form national highways, and connecting them with those which will be built by other countries is one for the Federal Government to solve rather than the individual States.

The first considerations in the design of highway systems are line and grade, but these are influenced by a great many other circum-

Mr. Schaeffer. stances. The most direct line between two large cities may be through a very hilly intervening country, and the best grades which could be obtained on a direct line might be prohibitive to heavy traffic. The maximum gradient to be used, therefore, will have to be determined before the horizontal location. The adoption of a maximum gradient will possibly increase the distance between the objective points very materially, but distance must always be sacrificed to grade. If a main highway is to be constructed between large cities, some distance apart, there may be smaller intervening cities lying to the right or left of the most direct line which might be located on account of the established gradient. It might be more economical to locate such a highway through these intervening cities, even at the expense of distance, than to connect them with the main highway by branch roads. It might also be desirable to follow along the foot of a hill where protection from the sun in summer and from snow in winter would be afforded by trees and shrubbery, instead of going directly across a barren plain. Where draft animals are used, fresh water may be a consideration to be taken into account. It will be seen, therefore, that there are a great many considerations which exert an influence on the location of a main highway.

The influences which the speaker has outlined as affecting the location of a highway, except the question of grades, apply more particularly to new highways. The routes of existing highways are already determined, so that there is less choice of selection.

The State engineer is often confronted by other problems. It is usually his duty to transform a country earth road into a modern first-class highway. In this case, also, the established maximum gradient should not be exceeded, even at the expense of changing the alignment. The other considerations probably have already been complied with. It may be necessary sometimes to straighten out some bad curves or to widen the roadway at curves, or at intersections, to reduce the danger of collision between fast-moving vehicles. When this is done, a judicious treatment of existing conditions is necessary. For example, an old roadway may be well sheltered by trees which protect both the road and the users of it. It would be folly to cut down these trees for the purpose of widening the roadway at an intersection where it might be possible to construct a new additional roadway behind them. This would provide two roadways, one for each direction of traffic, which would be better than one wide roadway and would save the trees which would give protection to both roadways.

Wherever possible, trees and shrubbery should be saved at all points along a public highway. The esthetic surroundings along such a highway have considerable influence on various phases of life. They will do much toward keeping people in the country instead of having them move to the cities. They also have a tendency to distribute

people from the cities in search of recreation instead of concentrating them in amusement and pleasure parks. Mr. Schaeffer.

The width of a roadway is a question which requires careful consideration, and is governed more by the character of the traffic than by any other factor. A long-distance, through highway, on which the traffic is usually of the high-speed variety, requires less width of roadway than a short road between adjoining villages on which there is a mixed traffic. Two automobiles require less width and less distance to pass than two trucks. A road connecting two villages often accommodates such a variety of traffic as automobiles, trucks, carts, pleasure carriages, perambulators, pedestrians, and children running loose. Such a road must obviously be wider than one which accommodates a less dense and more rapid traffic.

In addition to the kind of roads already described, there are those of less importance, which do not connect distant points, but connect smaller places with each other and with the main highways. In the United States these roads are destined to remain under the control of the local authorities for some time to come, and with but comparatively little improvement.

The design of highway systems applies to cities as well as to the country, and some of the requirements for a country highway apply also to city streets. Where it is proposed to lay out a system of streets for a new city, the problem is comparatively easy, but cities, as a rule, have not had their birth by design. The problem of the design of a street system is usually the planning of streets in territory adjoining a city already in existence, or the alteration of streets already built. Where the adjoining territory is undeveloped, the problem is also comparatively easy. Probably the most difficult problems in street design are the cases where a number of adjoining towns are annexed to a larger city. A good example of this is the annexation to New York City of the territory now known as the Boroughs of Brooklyn, The Bronx, Queens, and Richmond. Each of these territories comprised a large area of vacant land over which were scattered a number of small villages, the street system of each of which was oriented differently from that of the original city, and from one another. The solution of this problem is undoubtedly to develop into main arteries of traffic the old highways connecting the villages with the city and with one another by widening them sufficiently to accommodate the dense traffic which is sure to develop. As in country roads, it may also be necessary to straighten them, and this may be done with less regard for the surrounding topography than in the case of country roads, because their character will change as the city expands. The width of the roadway is also governed by the demands of traffic, but that of the street to which the city takes title should be governed in addition by the character of the develop-

Mr. Schaeffer. ment which will follow. In New York City, this development will probably be apartment houses, and therefore light, air, and access exert a more controlling influence than traffic. This is a factor which is often lost sight of, even at the present time. The result is that in the future, when expensive buildings occupy the streets, they will have to be widened at great expense.

The following summary, therefore, may be made:

The location and design of international and interstate highways should be undertaken by the Federal Government, that of other roads and streets by the State, county, town, or city, having jurisdiction over them.

The controlling influences on the location of highways are such grades as will be economical, both for traffic and construction, intervening cities and towns, topography, and vegetation.

For through city streets, the controlling influences are directions of route, sufficient width to accommodate traffic, and easy gradients; for streets of less importance, the location is governed by topography, and the frontage which will be provided for private development; the width is governed more by the requirements of light, air, and access, than by those of traffic.

Mr. Howard. J. W. Howard, Esq.—The road problem of a nation or state is entirely different from that of a city. The highway problem has unconsciously been largely discussed from the standpoint of pleasure automobiles, but the important point must not be forgotten, namely, that roads are built to transport vegetable and mineral products.

The German highway system in the Kingdom of Prussia is excellent, and especially in the Province of Hanover where it is designed to obtain the maximum wealth of the soil and convey it by the shortest routes to the centers for further shipment by rail to the ultimate consumers in cities, and for export.

The radial system should be designed to reach out as far as possible from a city. Many fine highways may be built, but unless they are linked with little farms and country places, their real economic purpose will fail. Local roads are part of a system. They can be narrower, and can be constructed with less expensive surfaces than main arteries, but they must be just as viable as the main highways; otherwise, the products of the soil are blocked from coming to the great cities. This system of main roads and laterals likewise distributes the products of the central producing factories, back to the people who have extracted and supplied the products of the earth: the true wealth producers of a nation.

Mr. Carter. C. E. Carter, Assoc. M. Am. Soc. C. E.—A comprehensive system is needed to connect all the towns throughout the State. The town should connect with the State system, thereby making a tentative

system through its limits (considering only the town system, regardless of ownership). At present, a man who owns a small piece of land divides it into house lots and locates the streets without consideration of the continuity of the highways. If the town system is already laid out, then development should be allowed only along these lines, unless any change suggested would better or, at least, not be detrimental to, the town system as a whole. This can be accomplished by the town refusing to accept streets, or allow municipal improvements to be placed in any street not shown in the system or subsequently approved by the proper authorities. Mr. Carter.

F. O. WHITNEY, M. AM. SOC. C. E.—Like most of the large cities of the United States, Boston is made up of several other cities and towns which have been annexed at different times, and each of these cities and towns contained several centers. In 1891 the State of Massachusetts passed an act requiring the City of Boston to appoint a Board of Survey, the duties of which should be to plan, immediately and as expeditiously as possible, a street system for the whole city, and such a Board was appointed. In 1895 its duties were transferred to the Board of Street Commissioners which has charge of the laying out of all streets in the city, and since that time it has constituted the Board of Survey in compliance with the original law. Mr. Whitney.

The law provided that these streets should be planned, and that their directions, widths, and grades should be determined, plotted, and indicated on maps. This work was done very thoroughly, the undeveloped portions of the outlying districts of the whole city being covered.

Particular attention was given to three classes of streets:

First, the connecting thoroughfares between the different centers of population and business. These were made as direct as possible by widening and straightening the old streets. The new widths were determined by considering the probable future traffic, and the grades were made as easy as possible in consideration of that traffic. Those streets were the arteries.

Second, the residential streets, which filled in the undeveloped spaces between the little villages. Their alignment was less direct. The grades were allowed to be steeper where necessary, and the widths, of course, much less than those of the thoroughfares.

Third, a class of roads which provided for pleasure travel, and was largely in connection with the parkways and the park system reservations of both the State and city parkways.

The law required that whenever public convenience demanded that streets should be constructed and laid out as public highways, the plotted lines and grades should be followed, and that private individuals, in the development of their property, should also conform to the lines thus laid down. The penalty imposed on individuals for not following

Mr. Whitney. these lines is that the city is prohibited from placing any public works in private streets which are not constructed on these lines and grades.

The topography of Boston is such, and the settlement of the territory has been so complete in centers, that it has been impossible to make the city over on any rectangular or other systematic development; but the irregular development has been considered by some as ideal from an esthetic standpoint.

Mr. Blanchard. A. H. BLANCHARD, M. AM. SOC. C. E.—Highway systems may be considered from the standpoints of the nation, state, county, township, city, town, and park. In this discussion the problem of design will be limited to a consideration of national, state, and county or township systems. City and town planning present many features peculiar to each, the consideration of which is not necessary in the design of the systems classified above. The design of highway systems includes consideration of the social, industrial, and agricultural development of a country; the inter-relationship between highways, railways, and waterways; the methods of transportation which will probably be used, such as horse-drawn vehicles, commercial motors, motor-busses, and light railways; and the limitations of grades on the different types of roads and pavements for each kind of traffic.

A national system for the United States would necessarily include trunk highways traversing the country from east to west and from north to south, and passing through the great centers of population, and through trunk highways forming connections between the important cities and these main highways.

State highway systems should be developed on the French plan, that is, main trunk highways constructed at the expense of the State, and county highways constructed by State aid under its supervision. Town highways may or may not be constructed with financial aid from the State, but they should receive the advantages accruing from such aid through the medium of its engineering department, as typified by the practice of the State of New York.

With the adoption of this plan of financing the construction of State, county and town highways, it becomes practicable to design a comprehensive system of State trunk highways connecting all important industrial, agricultural, and social centers.

The county system may be built up within the State system on the same principle, but from the local county standpoint. Under this plan, except in congested districts, town highways will generally be feeders to the State and county systems. It is obvious that the different classes are laid out by the unit of government directly affected. It is likewise apparent that if in a lower unit rests the responsibility covering improvement of highways of general interest to a higher political unit, vexatious and costly delays in the completion of the system of trunk highways will probably occur.

EQUIPMENT FOR THE CONSTRUCTION OF BITUMINOUS SURFACES AND BITUMINOUS PAVEMENTS.

FRANCIS P. SMITH, M. AM. SOC. C. E.—The earliest bituminous pavements laid in America were made with coal-tar, and the first mixing methods were very crude indeed, hand labor being used almost exclusively. By degrees, suitable machinery was devised, and, as the industry grew and sheet-asphalt pavements were introduced and became popular, the development of paving plants was very rapid. In large cities, where the area of pavement to be laid was great, the plants were built as permanent fixtures. Where only a limited amount of work was to be done, the investment was too great, and the semi-portable plant was therefore developed. This was designed so that it could be taken down, shipped to some other place, and set up again, without too great expense. Next, the railway plant, built on flat cars, was devised. This was a great improvement, as it could be taken down or set up in a few hours, and was entirely self-contained. A very large number of plants of this type are now in use in the United States. Mr. Smith.

The permanent, semi-portable, and railway types are used chiefly in paving town and city streets, as hauling is expensive, and, in order to operate economically, the plants must be placed near the street or road to be paved. Where large and heavy machinery is involved, its economical transport, of course, is confined to railroads, which are an absolute necessity where such plants are concerned.

The comparatively recent and rapid development of the bituminous concrete type of construction for country highways has resulted in still another plant. Such highways are frequently, perhaps usually, too distant from railroads to make it possible to locate a mixing plant on the line of the railroad and economically haul the hot mixture from it to the work. Even if this could be done, the contracts, owing to local conditions, are frequently let to small contractors who are not able to purchase large mixing plants. Within the last few years, therefore, a number of plants have been designed which, for lack of a better term, will be described as of the concrete-mixer type. Their output is relatively small, and their use is chiefly confined to highway work. They are not as economical or as complete as the larger plants, but when properly operated, there is no doubt that they have their field of usefulness.

As the various types of plants have been described elsewhere, it has seemed more important to the speaker to discuss the principles involved in their design and operation than to attempt to describe them in detail.

Regardless of the type of plant used, three distinct operations are involved in the manufacture of bituminous pavements by the mixing method:

Mr. Smith.

1.—Drying and heating the mineral aggregate,

2.—Preparing and heating the asphalt cement or bituminous cementing material,

3.—Mixing the hot mineral aggregate with the hot asphalt cement.

In a properly designed plant, the machinery for conducting each of these operations must be capable of handling sufficient material to insure the required output. This is a very important consideration, with reference not only to the time required to complete the work, but also to the quality of the mixture. Given ample mixing capacity, but insufficient drying and heating capacity, there will always be a strong temptation to rush the material through the dryer and mix it with the bituminous cement before it is dry enough and hot enough to insure the proper coating of the mineral aggregate. With the conditions reversed, the time of mixing each batch will be reduced in order to keep up with the output of the dryer, and this, of course, will result in a defective mixture in which the bituminous material is not evenly distributed throughout the mass and the various particles are not completely coated.

Where the drying and mixing are done in the same drum, as in the modified concrete-mixer type, the temptation first mentioned is always very strong. Furthermore, it is hard to obtain correctly the temperature of broken stone, under the best conditions, and in most plants of this kind it is difficult to get at the stone to test it, even if the machinery is stopped. Frequent stoppages, of course, will be strongly objected to by the contractor, and, besides, thermometers are frequently broken in this kind of work. Add to this the fact that these plants are usually run by men who are somewhat inexperienced (in fact, this is given by some manufacturers as one of the great arguments in favor of this type of plant), and it is not difficult to account for some of the unsatisfactory results obtained.

To understand more clearly just what is involved in the three operations mentioned, they will be considered separately.

Drying and Heating the Mineral Aggregate.—The mineral aggregate usually consists of sand, broken stone, gravel, or mixtures of these, and, depending on the kind of pavement to be laid, requires heating to a temperature between 250 and 350° Fahr.

Notwithstanding the fact that actual paving work is not usually carried on in rainy weather, it is frequently necessary to run very wet sand or stone through the dryer, owing to its exposure to the weather or because freshly dredged sand is being used. Unless ample drying capacity is provided, therefore, the output of the plant when using wet mineral aggregate will be greatly reduced. Many pavements are laid late in the fall or in early winter, and, under these conditions, much greater drying capacity will be required than in warm weather. Where the conditions vary as above described, or late in the season

when the difference in temperature between early morning and noon is very great, any attempt at regulating the drying operation by allotting a fixed time for it, which is adhered to without change during the day's operations, is absurd and useless. The temperature of the mineral aggregate must be tested, preferably with a thermometer, at frequent intervals, and the heating period must be changed from time to time as found necessary, and regulated in accordance with the results obtained. Mr. Smith.

In an asphalt plant, over-heating has to be guarded against carefully and continually, yet the heating capacity of the concrete-mixer type of road plants is usually so limited that the tendency is to underheat rather than over-heat the mineral aggregate. Care should be taken, of course, to prevent over-heating in all cases.

When a mixture of sand and stone, or stone of different sizes is being used, care must also be taken that each batch of material is of relatively the same mesh composition. This requires great care in feeding the mineral aggregate to the dryer, and, unless this point is insisted on, the average contractor will totally neglect it, and the resulting pavement or roadway will be hopelessly lacking in uniformity. Generally speaking, a fine mixture requires a greater quantity of bitumen than a coarse one. With the same quantity of bituminous cement to each batch, marked variations in the mesh composition of the mineral aggregate will result in a pavement which is too rich in some spots and too lean in others. In the case of the bitulithic type of pavement, in which the grading of the mineral aggregate is probably carried to the highest point, uniformity of mesh composition is obtained by screening the heated stone into separate bins and recombining the different sizes in definite proportions by weight.

Preparing and Heating the Asphalt Cement or Bituminous Cementing Material.—In sheet-asphalt paving work, the refined asphalt is usually fluxed to the proper consistency with a heavy residuum oil or flux, although in some cases a ready prepared asphalt cement is used. In road work, a bituminous cement of the proper consistency and requiring no fluxing is almost always used. It should be melted in kettles, preferably of sufficient capacity for the day's run, and constructed so that they will not tend to over-heat or unduly harden the material. The kettles should be fairly deep, rather than shallow, as this will minimize the hardening of the melted mass because of the relatively smaller surface exposed for the evaporation of the lighter oils. The best practice is to apply a slow fire until the material in the kettle is thoroughly melted, and then bring it up to the temperature desired, usually about 300° Fahr. Where the kettle capacity is small and it becomes necessary to re-charge it while in use, the tendency is to increase the heat unduly in order to melt the material rapidly to supply the demands of the mixing plant. This is especially true where a relatively hard and solid bitumen is being used. It must

Mr. Smith. always be remembered that the bituminous materials harden when exposed to long-continued or high heat; and, when, for any reason, the material in a melting kettle is kept heated for an unusual length of time, sufficient flux should be added to restore it to its original consistency. This is well understood in the asphalt paving industry, where the consistency of each kettle of asphalt cement is determined by the penetration machine before it is used, and is brought to the proper point from time to time by the addition of flux.

The average road contractor pays no attention to these details, in fact, is usually ignorant concerning them, and the speaker often wonders that his work turns out as well as it does.

Mixing the Hot Mineral Aggregate with Hot Asphalt Cement.— In the sheet-asphalt paving industry, what is frequently termed a twin pug type of mixer is used. In this there are two parallel shafts, revolved by suitable gearing, and attached to them are blades which intermesh with each other and are at different angles on the shaft (somewhat in the same way that propeller blades are placed), so that they will throw the mixture from the ends and sides toward the middle. Some revolving-drum mixers of the concrete type are provided with blades to facilitate the mixing, and some are not. Some are heated from the outside and in others the products of combustion pass directly through them. The time required for mixing a batch depends on its size and the efficiency of the mixer. This must be determined for each plant, and, once determined, should be adhered to rigidly. In no case should the mixing process be commenced until the mineral aggregate and the bituminous cement are at the proper temperature. Assuming that the mixing period is comparatively short, it is unnecessary, and a distinct disadvantage under ordinary conditions, to have the mixing drum heated or the products of combustion pass through it during the process. The bituminous cement, when applied to the mineral aggregate, coats the particles with an extremely thin layer, therefore, at this stage of the operation, it is peculiarly susceptible to hardening by excess of heat. If the mineral aggregate and bituminous cement are heated to the proper temperature in the first place, the bituminous material will remain sufficiently liquid during the mixing process to coat the stone properly. If either of them is too cold when they are brought together, they should have remained longer in the dryer or melting tank, and, for the reason above stated, no attempt should be made during the mixing process to bring them up to the temperature which they should have reached before they were mixed.

A paving mixture made with too hard an asphalt cement will be very difficult to rake or spread, and impossible to compress properly at the temperatures at which normal mixtures are ordinarly handled on the street. Raising the temperature of the mixture only tends to harden it still further. Mixtures containing too hard an asphalt cement will not give proper service, as they will crack in cold weather

and grind out under traffic, and do not provide any margin of safety for offsetting the hardening action of time on all bituminous materials. Mr. Smith.

Of course, it is not necessary to state that the proportions in each batch should be weighed or measured accurately. In asphalt plants of the best type, each ingredient entering into each batch is weighed carefully. Where measuring is resorted to, this is done accurately by striking off the mineral aggregate carefully in special iron measuring boxes, and filling the asphalt bucket until the contents reach the level of a proper measuring gauge. Contrast this with the usual road contractor's method of operations and one will see a vast difference. In the speaker's opinion, it is not too much to say that uniformly good results will never be obtained until the methods used in constructing bituminous roads are closely patterned after those followed in the asphalt paving industry.

It may be interesting and instructive at this point to discuss somewhat in detail just what quantities of material pass through the three different processes previously mentioned for a given yardage of pavement. For this purpose, consider a sheet-asphalt plant having a capacity of 2 000 sq. yd. of 2-in. wearing surface per working day of 10 hours. The average weight of 1 sq. yd. of surface mixture 2 in. thick when compressed will be 200 lb. The total weight of the output, therefore, will be 2 000 $\times$ 200 = 400 000 lb. This mixture will consist approximately of:

Sand	79 per cent.
Dust or filler	10 " "
Bitumen	11 " "
	100 per cent.

The different portions of the plant, therefore, must be capable of handling the following quantities of material:

Dryer	316 000 lb.	= 126.4	cu. yd. of sand,
Melting tanks	44 000 "	= 22	tons of pure bitumen,
Mixer	400 000 "	= 200	tons of surface mixture.

The capacity of the mixer in a plant of the size under discussion is usually rated at 9 cu. ft. This means that the batch dumped into it contains 9 cu. ft. of sand plus the other ingredients. The average weight of dry, hot sand is about 95 lb. per cu. ft. In accordance with the formula previously given, and assuming that a pure asphalt cement is being used, each batch would consist of:

Sand	855 lb.
Filler	108 "
Asphalt cement	119 "
	1 082 lb.

Mr. Smith. It will take 370 batches of this size to turn out the required quantity of surface mixture. In a 10-hour working day, this means 37 batches per hour, or one batch every 1.62 min. Not less than one full minute, with a mixer speed of from 60 to 80 rev. per min., should be allowed for actually mixing each batch of sheet-asphalt surface mixture. This leaves a total of only 37 sec. in which to charge the mixer with the various ingredients and dump the finished mixture into the wagons. With a well-organized gang and a properly working plant of this type, only 20 sec. are necessary, but it can readily be seen that this is one of the features where seconds count. The mixer capacity of a plant is usually calculated very closely, and this makes it more than ever necessary that the capacity of the melting tank and dryer should be ample in order to furnish a full and uninterrupted supply of hot sand and asphalt cement, as it is almost impossible to make up for delays at the mixer.

Having determined the formula for any piece of work, and knowing the time required for mixing each batch, together with the size of the batch, one can calculate a similar schedule of operations for it, and ascertain just what kind and capacity of plant is suitable for the work. After determining these points, a contractor should never be permitted to mix and lay more pavement in a given time than is called for by the schedule. If he does, it is certain that some portion of the work has been slighted. This should be carried still further, if necessary, by determining the maximum number of batches permissible per hour and never permitting him to exceed this in an endeavor to make up by hasty work in an afternoon what he has lost in the morning on account of unfavorable conditions of any kind.

As stated previously, a standard sheet-asphalt pavement, 2 in. thick, when compressed, weighs about 200 lb. per sq. yd. Road surfaces of broken stone or mixtures of broken stone and sand, 2 in. thick, will vary from 175 to 250 lb. per sq. yd. The denser the mixture and the greater the proportion of large stone, the greater will be the weight per square yard.

After the mixture has been made, delivered to the road, and spread, it is necessary to roll it in order to compress it. Either of two types of rollers may be used for this purpose. The tandem type is generally used in laying sheet-asphalt pavements, and the road roller type (in which the wheels do not track) for highway work. Where the mineral aggregate is composed of small-sized particles and requires to be finished to a very smooth surface, as in city pavements, the tandem type of roller will produce better results and a more even surface. Where the particles of mineral aggregate are large, the type of roller generally used in road work is better for the purpose. It gives a greater kneading action to the large particles, and will effect better com-

pression in such a surface than can be obtained with a tandem roller of the same weight per inch of width of tread. In addition to this, the total width of tread in a road roller is less than in a tandem roller of the same weight, and, therefore, gives a greater pressure per square inch. It is somewhat more difficult to finish the work smoothly with the road roller, but, for ordinary road or highway work, this is not as essential as for city streets. Mr. Smith.

Distributors.—The oiling of roadways results in the formation of a bituminous surface, and would therefore come under the present discussion. The chief piece of apparatus used in this kind of work is a distributing wagon for the oil or bituminous material. Where this oil is so heavy that it will not run freely at ordinary temperatures, it is necessary to provide means for heating it, either in the distributing wagon itself or in the tanks from which this wagon is filled. Such wagons are of two general types: gravity distributors, and pressure distributors.

The gravity distributors apply the oil to the road more or less uniformly and in a film of considerable thickness. This film, if of heavy oil, requires a long time to be absorbed by the roadbed, and, in order to make traffic on it at all agreeable, it is necessary to sprinkle gravel or sand over the surface of the oil as soon as it has been applied, otherwise it will be tracked into houses and spattered over vehicles and people riding in them. With a distributor of this type, the absorption of the oil by the roadbed is accomplished entirely by capillary action.

Pressure distributors are of two kinds. In one the oil is forced through small orifices in the distributing pipe by maintaining air pressure in the top of the tank from which the oil is being drawn. Thus the oil is forced downward to a slight extent into the roadway, but there is still a sticky and oily film on the surface much like that produced by the gravity distributor. A large part of the absorption of the oil by the roadway is accomplished by capillary action, and is more or less slow. Roads treated by this method, though less objectionable than when the gravity distributor is used, will still require the application of a coat of screenings or sand on the surface.

In the other type of distributor the oil is atomized by the action of the air pressure, in much the same way as in perfume atomizers and oil burners. When properly designed, distributors of this type will apply to the surface of the road, with considerable force, a mist of very minute oil particles which will be driven downward at a high velocity by the air pressure. In this way the oil will be driven to a considerable depth into the roadway, and the treatment may be regulated so that on the surface of the freshly oiled road there will not be any objectionable quantity of oil, thus obviating the necessity of applying a coat of screenings.

Mr. Drowne. H. B. Drowne, Assoc. M. Am. Soc. C. E.—During the summer of 1912, the speaker supervised some construction work on the Service Test Road in Philadelphia, on which a portable mixing plant of small type was used. This mixer is known commercially as the Rapid Heated Mixer.

Essentially, the machine consists of a four-wheeled truck, at one end of which is mounted a boiler and engine, and at the other a small cylindrical rotary mixer. Between the boiler and the mixer is a platform on which the loading is done. The mixing drum is surrounded with a hood, furnishing a heating space of about 3 in. between the shell of the latter and the mixer. The heat for this hood is furnished by a coal fire directly under the mixer. Additional heat is obtained from a kerosene torch which may be inserted within the mixing drum. A vertical blade running spirally around the inside of the drum serves to lift the material from the bottom and carry it to the top of the mixer, as the latter revolves. The material then falls to the bottom, and the same operation is repeated. The discharge spout is fixed in the center of the drum at the rear of the machine. The capacity of the mixer is 12 cu. ft., or a batch of about 1 300 lb., including the bituminous cement.

In this instance, a Topeka pavement was being constructed. The aggregate was composed of a mixture of sand and stone complying with the following specification:

Passing	200-mesh	sieve,	5 to 11	per cent.
"	40- "	"	18 to 30	" "
"	10- "	"	25 to 55	" "
"	4- "	"	15 to 22	" "
"	2- "	"	not more than 10 per cent.	

The various materials were taken from the stock piles in wheelbarrows to the loading platform and dumped into the mixer. The kerosene torch was then inserted within the drum, and, as the mixer revolved, the material cascaded through the flame of the torch and was heated to a temperature of about 212° Fahr. When this temperature was reached, the torch was withdrawn, and the asphalt cement, which was heated to about 350° Fahr., was poured in. A cover was then placed over the opening in the loading end of the mixer. The batch was allowed to mix with the asphalt for from 1 to 2 min., at the end of which time a perfect mix was secured having a temperature of 250° Fahr.

The output of the machine varied, depending on the dryness of the mineral aggregate. On an average, from four to five batches were mixed per hour. When the materials were warmed before being put in the mixer, six batches per hour were mixed for 1 or 2 hours, or as long as the warm material lasted. One batch of material would lay

Mr. Drowne.

about 5 sq. yd. of pavement, 2 in. thick when rolled. The pavement was constructed on a macadam foundation, and there was some loss, due to the material being compressed into the voids of the surface. If laid on a concrete foundation, one batch would probably have made a somewhat greater yardage. The manufacturers of this machine claim an output of 250 sq. yd. per 10-hour day per machine. It is generally recommended that these machines be used in pairs. It takes from 6 to 12 min. to bring the material up to the proper temperature before adding the asphalt cement. If only one machine is used, and four or five batches per hour are mixed, the time required for each batch is from 12 to 15 min., therefore, considerable time is wasted by the men working around the machine. If the machines are used in pairs, the men can be kept busy practically all the time, and it is the only economical way to use machines of this type. The output of two of them in a 9-hour day would be about 360 sq. yd. In a bituminous concrete in which the aggregate does not form so dense a mixture as the Topeka, but is composed of larger stone particles, the output of the machine is considerably increased.

If the cost of labor is $2 per day, seven laborers being required, and an engineer at $3.50 per day, the labor cost of the operation would be about 4.8 cents per sq. yd., on a basis of 360 sq. yd. per day. The cost of coal, kerosene for the torch, depreciation of the machine, and supervision, would add probably about 4.5 cents, making a total cost of 9.3 cents per sq. yd. It is essential that the stock piles, and the kettle in which the bituminous material is heated, be near the mixing plant, in order to accomplish economical work.

The importance of drying the material must not be lost sight of in using machines of this type, and this part of the operation takes up the greater part of the time. Some means of heating and drying the materials must be used before putting them into the mixer. On the Philadelphia work wood fires were built in pipes placed under the stock piles. This preliminary heating helped considerably, but if the materials were not covered with tarpaulins at night a slight rain would dampen them to such an extent that the mixing would be seriously delayed. With mixers of this type there is not the slightest danger of overheating the materials, provided the batches are discharged when they reach the proper temperature; but if they are left in the mixer too long they will become overheated.

This machine is also adaptable for mixing cement concrete. When used for this purpose, a swinging trough is fixed under the discharge spout. The mixed concrete falls from the spout into the trough, which has such a pitch that the concrete runs down to the end and falls on the road. As the trough is 10 ft. long and may be swung through an arc of 180°, a width of about 20 ft. of surface can be

Mr. Drowne. covered with concrete at one passage of the machine, without wheeling any of the concrete.

The speaker thinks a plant of this type is a good one for small jobs, or for repair work, where small plant cost is desired. These machines cost about $1 200 each.

Mr. Gaynor. JAMES L. GAYNOR, ESQ.—A rapid mixer was used during October and November for mixing 1½-in. stone with an asphalt cement. On an average, 350 yd. per day were mixed. Instead of using 12 cu. ft. to the batch, about 15 cu. ft. were used, the mixer being loaded full. The stone was bone dry. With a battery of two machines, a capacity of 700 cu. yd. per day should be secured. The labor charge for one machine was about 9 cents per cu. yd.

Mr. Poore. H. C. POORE, JUN. AM. SOC. C. E.—During the season of 1912, the speaker was connected with the construction of about 55 miles of bituminous concrete pavement. This work was done by one of the New England States, which, having had the usual experimental sections under test for the past 4 years, decided to use a cold-mixed bituminous concrete for both resurfacing and new work.

Refined coal-tar was used as a binder, this material being shipped in tank cars to the nearest railway station, where it was steam-heated and barreled by the contractor.

During the height of the season, eighteen mechanical mixers were in operation, laying daily a total of 3 000 ft. of 14-ft. road surface, 2 in. thick.

The type of mixer generally used was one manufactured by the Municipal Engineering and Contracting Company. It is similar to the ½-yd. cube batch cement concrete mixer, and has an oil torch heating device for use when bituminous concrete is mixed. The machine is mounted on four wheels for transportation. It consists of a revolving iron box, mounted on its diagonal axis, and driven with direct gearing by the steam engine mounted on the same frame. The mixed material is discharged by tipping the cube, and the mixing chamber is loaded with a sliding skip operated by a small cable hoist.

An air compressor for supplying the oil torch is belted to the engine. Common fuel oil under air pressure forms a blast in the center of the mixing chamber sufficient to dry the mineral aggregate and expedite the work during cold weather. As the specification called for a cold mix, the blast was not necessary throughout the day's work.

The plants were operated in two ways: either as a portable plant moving along the road each day, or as a stationary unit at the stone crusher.

The first method was followed where the work consisted of scarifying the old macadam and adding a new 2-in. bituminous concrete surface. Set-ups were made at the intervals covered in a day, usually

about 200 ft. A 12 by 12-ft. dumping board was used under the loading skip, on which to dump the broken stone hauled from the railroad siding or stone crusher. The mixer was placed on planks in the center of the road, being hauled ahead by the steam roller at the end of the day. Mr. Poore.

Two 15-gal. portable kettles provided sufficient hot bituminous material. The proper quantity for a batch was measured out by hand and carried in buckets from the side of the road to the loading chute. Six iron barrows, well oiled to prevent the coated stone from sticking, were used in carrying the hot mixture to the road, where it was raked out to the required depth.

One roller was able to prepare the old macadam and roll the mixture delivered each day. When the mixer was used as a permanent unit at the stone-crushing plant, the mixer platform was built at the same elevation as the bottom of the stone bins, and from the latter the stone could be discharged directly to the loading skip. To allow the uncoated stone for the foundation course to fall by gravity into wagons, it was necessary to leave an intervening space of 7 or 8 ft. between the stone bins and the mixer platform. In some cases, however, the mixer was placed on the other side of the bins, and then an extra chute was built to feed into the loading skip.

Many of the mixers ran three ½-cu. yd. batches in from 10 to 15 min. A 1½-cu. yd. bottom-dump wagon was placed to receive these three batches, and then hauled to the road, a 2-mile haul often being economical. There was no chilling of the mixture. A larger kettle was used at the stationary plants than on the resurfacing work. The buckets of hot bituminous material were handed from the ground by the kettleman to the man on the raised mixer platform, and he emptied them into the mixer chute.

One engineer, one helper, one loading man, and one kettleman were required for the mixer when in operation. The broken stone was not touched by hand until raked out on the road.

The cost of the plant was:

Mixer complete....................	$1 550
Two kettles........................	200
Small tools and lumber............	100
	$1 850

Practically 600 sq. yd. were turned out per day per plant. On country roads, where a cold-mix bituminous concrete is specified, such an equipment may be considered very satisfactory.

W. S. Godwin, Esq.—The cardinal point in bituminous paving is unquestionably uniformity. This applies to all the different methods of construction, surfacing, penetration, and mixing. Mr. Godwin.

Mr. Godwin. Irrespective of the method, cost, or kind of equipment, there are fundamental requirements which must not be ignored, if lasting qualities in the paving are expected. These can only be obtained by the proper use of appliances designed and built by those who are thoroughly familiar with the materials and the methods of construction.

In view of the fact that the cost of the product of the equipment is in inverse ratio to the volume of the output, economical production can only be obtained by having an output so large that the overhead cost does not assume undue proportion.

Cold Surface Treatment.—Bituminous materials can be properly and economically applied cold from a tank wagon drawn by motor or horse. It should have, across the rear, a distributor adjustable in width from 6 to 12 ft., thus avoiding the application of narrow strips. The distributor proper should have small openings or spraying nozzles at short intervals for the entire length, arranged so that they will entirely cover the desired width of roadway, and not apply the material in strips.

Unquestionably, the most difficult factor to control is the uniform distribution of the necessary quantity of bituminous material per square yard. This can be accomplished by keeping a uniform air or steam pressure in the tank, or by a pump connected between the tank and the distributor proper. Unsatisfactory results are obtained with either of these methods if the speed of the wagon or the motor varies. This objection, however, can be overcome by using a specially designed pump connected with the running gear of the wagon or truck, or by drawing the tank wagon by a steam roller at a uniform speed. Any of these distributors should be capable of distributing evenly from ½ to 1½ gal. per sq. yd.

Gravity distributors of any kind have the disadvantage of being able to handle only the light gravity oil; the quantity distributed also gradually decreases as the tank empties.

Hot Surfacing and Penetration Methods.—If the pressure distributors are equipped with interior steam coils, and sufficient steam is supplied to keep the bituminous material at a uniform temperature of about 280° Fahr., they are capable of distributing the heavier grades for either the hot surfacing or the penetration methods of construction.

The equipment generally used in the penetration method has been portable or semi-portable melting kettles, having capacities ranging from 50 to 500 gal., and hand-distributing pots. This method of heating and applying is expensive and the results obtained are invariably crude. The bituminous material is often too cold, and, in some cases, is overheated and damaged. It is quite apparent that when a pouring pot is used, the uniform distribution of the hot material depends entirely on the workmen. Even with the utmost care, non-uniformity

shows on the finished roadway. An excess of bituminous material will collect in spots and hold any kind of stone or dirt, even after the completion of the roadway. This causes an uneven surface which is very objectionable. Mr. Godwin

The arrangement and equipment for penetration work is most satisfactory when the contractor receives the bituminous material at the nearest railroad siding, in 6 000, 8 000, or 12 000-gal. tank cars, equipped with interior steam coils. A 20-h.p. boiler may be attached to the steam coils in the tank car and thus heat the material to the desired temperature. If this arrangement is provided at the railroad siding, the hot material may be run by gravity into the distributing wagons. If this is not practicable, the material may be pumped from the car to the wagons. A horse-drawn distributing wagon may be hauled from the railroad to the work and then may be attached to a steam roller.

Bituminous material received in barrels costs the contractor an additional sum of at least 2 cents per gal. for each barrel and also the freight on the barrels, which is about 15% of the gross weight. Besides, he has two or more melting kettles to operate and a very large bill for fuel to heat them.

A 20-h.p. boiler and a 600-gal. distributing wagon will cost about \$1 000, and, with an average haul from the railroad siding, should cover 800 sq. yd. per hour. Two 400-gal. melting kettles, at \$400 each, and a dozen buckets and pouring pots will cost about \$850, and will not cover one-half as great a yardage. It is a case of inferior construction at an exorbitant cost, if the proper equipment is not used.

Should the extent of the work not warrant the purchase of such a plant, there should be secured a strong, well-built 500-gal. melting wagon and a hand distributor, having a capacity of at least 30 gal., mounted on wheels, and having a regulating distributor at least 20 in. wide. A distributor of this kind costs \$65, and should pour 250 sq. yd. per hour, using 1½ gal. in the initial pouring and ½ gal. in the flush coat. The use of pouring pots should be avoided if possible.

Mixing Methods.—In the manufacture of bituminous mixtures of any kind, uniformity is the principal factor. This applies, not only to proper proportions of each different ingredient used, but to the temperatures at which they are heated and mixed.

The mineral aggregate, composed of stone, sand, and inorganic dust, must be heated uniformly to the proper temperature, and in such a way as to prevent segregation of the larger from the smaller particles. This is a serious matter when different proportions of two or more sizes are used. The aggregates are usually heated in a cylinder dryer, with external heat. The heat is then drawn through the interior, the different sizes, in the proper proportions, being fed continually

Mr. Godwin. through the hot cylinder. If a batch heater and mixer is used, the proper proportions are measured or weighed before being placed in the mixer.

The kettles must have sufficient capacity to provide the quantity of bituminous material required to coat the mineral aggregate as it is heated by the dryer. The heat should be uniform and not so great that it will "burn," or harden any portion of the material. The melted material should be agitated slowly by compressed air. This is especially necessary where two kinds are used to obtain the proper consistency. The melting kettles should be protected from the rain, as water not only damages the bituminous material, but causes it to foam and run over the sides of the kettle, in some cases causing serious fires.

The quantity of hot material for each mix or batch should be measured or weighed accurately, and not mixed with the mineral aggregate until the stone or sand is of the proper temperature.

The hot mineral aggregate and the hot bituminous material should be mixed quickly and uniformly, with as little loss of heat as possible. The resulting homogeneous mixture should be spread quickly and evenly with strong iron-shank rakes and thoroughly rolled on a solid foundation.

If a portable batch mixer, having an interior flame in the drum, is used to mix the heated mineral aggregate with the bituminous material, the heat must be cut off before the latter is placed in the mixer, otherwise the excessive heat will damage it. Any method of mixing which allows the bituminous mixtures to come in contact with the flame or a heat in excess of 500° Fahr., if only for a short time, will convert the bituminous material from an adhesive and malleable consistency to a hard and brittle one, entirely unsuited for paving.

To receive their ultimate compression, mixtures similar to bituminous macadam and bituminous concrete, having a large percentage of stone, should have their final rolling with a 3-wheel roller weighing at least 10 tons. If a 5-ton tandem roller is used for the initial rolling, a more uniform surface will be obtained on the finished paving. The same method of rolling should be used for sheet asphalt, but both the rollers should be of the tandem type and weigh 2½ and 7 tons, respectively.

These fundamental principles must be adhered to, in order to obtain uniform and lasting paving, irrespective of the method and equipment used.

The cost of heating and mixing plants depends principally on their capacity and the care and material used in their construction. A small portable batch heater and mixer, similar to a concrete mixer, and capable of heating and mixing about 7½ tons per hour to a temperature of 200° Fahr., costs $1 500. Mixers of this class are only

capable of mixing stone which is larger than ¼ in. As the bituminous material is placed in these mixers hot, a 500-gal. melting kettle is required. Mr. Godwin.

For close or dense mixtures, stationary, semi-portable, and railroad plants are used.

Semi-portable plants, comprising the heating drum, mixer, melting tank, etc., cost $7 500, exclusive of any building, and have a capacity of about 75 sq. yd., or 7½ tons, of sheet-asphalt mixture per hour.

The improved railroad plants, which cost about $12 000, are capable of heating and mixing sufficient asphalt and sand to a temperature of 325° Fahr., to lay 175 sq. yd., or 17½ tons, of sheet asphalt mixture per hour.

The modern duplex stationary plant, in which the large dryers, 15-cu. ft. mixers, conveyors, etc., are operated with independent motors, cost about $33 000, including a steel building. These plants have a capacity of 500 sq. yd., or 50 tons, of sheet-asphalt mixture per hour.

As mixtures of stone are laid at a lower temperature and require less bituminous material than sheet asphalt, the capacity of plants increases about 18% when heating and mixing for paving of this class.

In buying a bituminous mixing plant of any kind, the contractor or municipality should receive bids only from companies which have had considerable experience in the manufacture of such machinery. It should be required that the plant be erected and operated under the direct supervision of the builder until it has met the guaranteed requirements. The guaranty should be for a certain number of pounds of properly heated paving mixture at a specified temperature, per day of 10 hours, and not a certain number of square yards. As all dense bituminous mixtures, when compressed to 2 in., weigh very nearly 200 lb. per sq. yd., this portion of the guaranty can easily be changed from square yards to something which is definite and easily ascertained. The contract should also state the maximum quantity of fuel to be consumed in 24 hours, and last, but not least, the date when the finished plant will be completed, erected, tested, and ready to run to the guaranteed capacity.

W. H. Kershaw, Assoc. M. Am. Soc. C. E.—There is one class of equipment which has not been given proper consideration, and that is storage plants for road oil. Mr. Kershaw.

Equipment is acquired or improved because of the increased efficiency or saving in cost accomplished by its use. If it was thoroughly understood that equipment for the temporary storage of road oils, tars, and asphalts would earn a satisfactory return on the investment, interest in this branch of road work would be increased.

It has been the custom in the past, when buying light oil, heavy binding oil, tar, or asphalt, to order one or more tank-cars, and then

Mr. Kershaw.

hold the cars until the material has been used. With the exception of one or two companies, no charge per day for demurrage on cars has been made for the use of this equipment. A charge of $1 per day is collected by the railroads in all cases, but, of course, none of this goes to the owner of the cars. The economic loss resulting from holding tank-cars out of service has been considered to fall on the shipper, but in the final analysis it is apparent that the price of the oil must cover the loss. Just what this loss of service for a single tank-car amounts to can be better understood when the following figures are considered.

At present, the leasing value of a tank-car is about $1.25 per day; that is, the seller either pays that amount in the form of a lease or, if he owns the equipment, can, in turn, lease it to some one else for that figure. This $1.25 per day practically covers the maintenance and depreciation of the car, and does not include an earning on the equipment which its owner is justified in expecting. A study of Table 1, which gives the time consumed in delivering a full carload (8 000 gal.), by the same car, to cities with and without equipment, shows the injustice of allowing the same tank-car charge to apply for all deliveries.

Table 1 gives an actual record of several cars which were in the road-oil service in the East during 1912, but for convenience the cost figures are based on a leasing value of $1 per day. In considering this record, it must be borne in mind that the producer or seller is carrying his tank-car equipment for 12 months in the year, and during the road season (from 6 to 8 months), is using the cars to the limit of their capacity. For the remainder of the year he has nothing for them to do or is turning them into some branch of the service which does not bring him an adequate return for their use.

From this table it will be noted also that a car can be shipped to a town or a city having equipment, and make a round trip in from 9 to 15 days, at an actual cost of from $12 to $25, delivering in that time a full load of 8 000 gal. When the tank-car charge on business of this class is added to the base price, it makes possible a lower quotation than can be given on deliveries made to points without equipment, where the car is gone from 20 to 100 days, in delivering the same quantity of oil. The shippers are ready to make lower quotations to cities equipped with storage plants, than can be made to points where their cars are delayed.

The fact that the installation of this equipment results in a material saving has been recognized by several of the large users of road oil, as witnessed by the following examples.

District of Columbia.—The District of Columbia has erected six 12 000-gal. and one 15 000-gal. road-oil tanks, these tanks being situated at various points throughout the District convenient for distribution.

Three of the tanks are at the Property Yard of the District of Columbia, at 12th and N Streets, Northeast, on a siding of the Baltimore and Ohio Railroad. Fig. 1 shows only the 15 000-gal. tank of this particular group. There are two 12 000-gal. tanks directly under the railroad trestle. All these tanks are fitted with steam coils. Between the two 12 000-gal. tanks, and extending out under the end of the railroad ties, there is a mixing box, containing a mixing pug, and there are both water and oil inlet pipes, for the manufacture of emulsified road oil. Mr. Kershaw.

TABLE 1.—RECORD OF TANK-CARS.

Car no.	Consignee: With or without equipment.	Date shipped.	Date returned.	Number of gallons.	Number of days car is held at oil company's terminal.	Number of days required to make the round trip.	Cost of car, based on leasing value of $1 per day.	Earning capacity of car, in gallons per day.
017060	City (with)..........	5/ 1/12	5/ 9/12	8 000	0	8	$8	1 000
017060	Town (without)......	5/ 9/12	5/27/12	8 000	0	18	18	444
017060	City "	5/29/12	6/20/12	8 000	2	22	22	363
017060	City (with)..........	7/11/12	7/22/12	8 000	*21	11	11	727
017060	City "	7/22/12	7/30/12	8 000	0	8	8	1 000
014480	City (without).....	4/15/12	5/ 3/12	8 000	0	18	18	444
014480	City "	6/11/12	7/ 6/12	8 000	†37	25	25	320
014480	City (with)..........	7/ 6/12	7/16/12	8 000	0	10	10	800
014480	City "	7/16/12	7/24/12	8 000	0	8	8	1 000
014480	City (without)......	8/ 3/12	8/16/12	8 000	9	13	13	615
011150	City (without)......	4/11/12	4/27/12	8 000	0	15	15	533
011150	City "	4/27/12	5/31/12	8 000	0	34	34	235
011150	City "	5/31/12	7/ 2/12	8 000	0	31	31	258
011150	State "	7/ 3/12	8/ 8/12	8 000	1	35	35	228
011150	City (with)..........	8/12/12	8/26/12	8 000	4	13	13	616
011150	City "	8/31/12	9/ 9/12	8 000	5	9	9	888
014680	City (without)......	5/ 4/12	5/27/12	8 000	0	22	22	363
014680	City "	5/31/12	6/20/12	8 000	4	20	20	400
014680	City (with)..........	7/10/12	7/20/12	8 000	*20	9	9	888
14680	Town (without......	7/23/12	9/16/12	8 000	3	54	54	148
013600	City (with)..........	5/27/12	6/ 4/12	8 000	0	7	7	1 143
013600	City "	6/ 7/12	6/13/12	8 000	3	5	5	1 600
013600	City "	6/13/12	6/20/12	8 000	0	6	6	1 333
013600	State (without).....	7/ 3/12	8/14/12	8 000	13	42	42	190
014600	City (without)......	4/ 9/12	5/ 4/12	8 000	0	25	25	320
014600	Town "	5/ 4/12	6/ 3/12	8 000	0	30	30	267
014600	Town "	6/18/12	7/ 9/12	8 000	*15	21	21	380
014600	City (with)..........	7/ 9/12	7/22/12	8 000	0	13	13	615
019260	Town (without).....	6/25/12	7/11/12	8 000	0	16	16	500
019260	State "	7/11/12	10/18/12	8 000	0	100	100	80

*Car made trip with material other than road oil

†For repairs.

There is a single 12 000-gal. tank at each of the following outlying points: Chevy Chase, Md., Deanwood, Uniontown, and Tacoma Park, D. C. Fig. 2, the 12 000-gal. tank at Tacoma Park, shows the type of

Mr. Kershaw.

equipment in the several suburban districts mentioned. All the tanks have heating coils, and the average cost of the 12 000-gal. tanks in place, complete, including coils and erection charges, was $600.

Springfield, Mass.—The storage equipment at Springfield, Mass. (Fig. 3), consists of two 10 000-gal. tanks, carried on concrete footings. These tanks are arranged so that there is a fall of 2 ft. from the bottom of the tank-car, as it stands on the trestle, to the top of the receiving tank, and a fall of 2 ft. from the bottom of the receiving tank to the top of the distributing wagon. Each tank cost $344, f. o. b. Springfield, Mass., and the cost of installation, including piping, was $812, making the total cost $1 500. These tanks are single compartment and have no heating coils.

Borough of The Bronx, New York City.—This Borough bought four 6 000-gal. tanks, formerly used as railroad tank-cars, and assembled them on wooden trestles, arranging the piping so that the oil could be run into any tank desired. This was accomplished by placing a continuous main oil line with a shut-off valve on each tank connection. Figs. 4 and 5 show the arrangement of the tanks and piping.

These four tanks cost $950, f. o. b. New York. The construction of the wood trestles and the concrete foundations carrying them, together with the erection of the tanks and the complete piping, cost $750. The cost of painting the tanks and pipes was $70, making the total cost $1 700 for the complete equipment. The difference in elevation between the railroad track and the bottom of the pit makes it possible to fill the storage tanks and, in turn, load the tank-wagons from storage by gravity. These tanks are at 202d Street and Webster Avenue, on a siding of the New York Central Railroad.

Greenwich, Conn.—The Town of Greenwich, Conn., has a two-compartment tank of 12 000-gal. capacity, one compartment being fitted with steam coils. Fig. 6 shows the arrangements of the tank, which is in the side of a railroad fill, thus allowing enough fall to transfer the oil from the tank-car to the storage tank, and from storage to the distributor, by gravity. The cost of this installation was rather high, owing to the number of concrete abutments required to carry the pipe line from the tank-car to the tank and from the tank to the driveway. The cost was as follows:

Tank, f. o. b. shipping point	$327.96
Freight	52.00
Piping	165.00
Concrete abutments	230.00
Painting	15.00
Extras	5.00
Total	$794.96

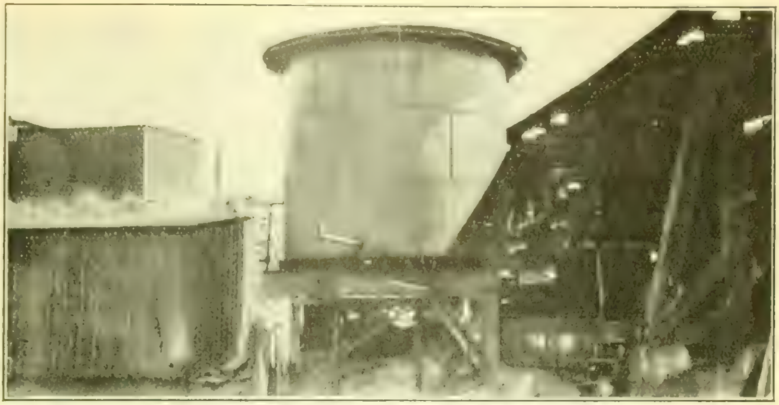


FIG. 1.—15 000-GAL. STORAGE TANK, 12TH AND N STREETS, WASHINGTON, D. C.

FIG. 2.—ROAD OIL TANK, TACOMA PARK, WASHINGTON, D. C.

FIG. 3.—ROAD OIL STORAGE TANKS, CITY YARD, SPRINGFIELD, MASS.

MUNICIPAL OIL STORAGE TANKS, BUREAU OF HIGHWAYS, BOROUGH OF THE BRONX.

FIG. 4.—ARRANGEMENT OF TANKS.

FIG. 5. ARRANGEMENT OF PIPING.

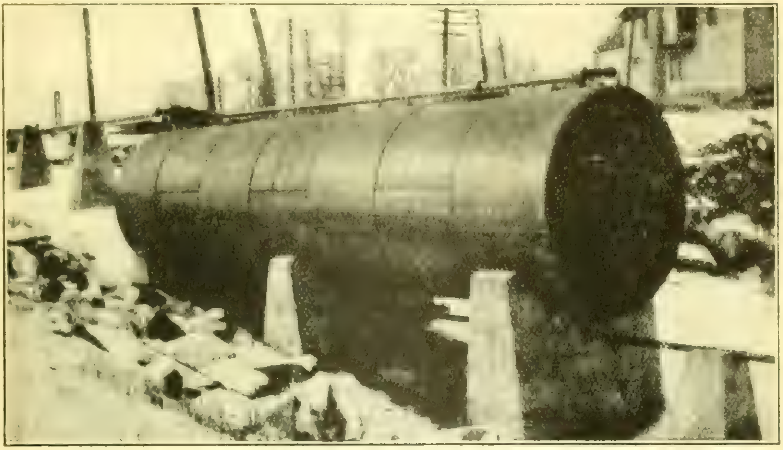


FIG. 6.—STORAGE TANK FOR ROAD OIL, AT GREENWICH, CONN.

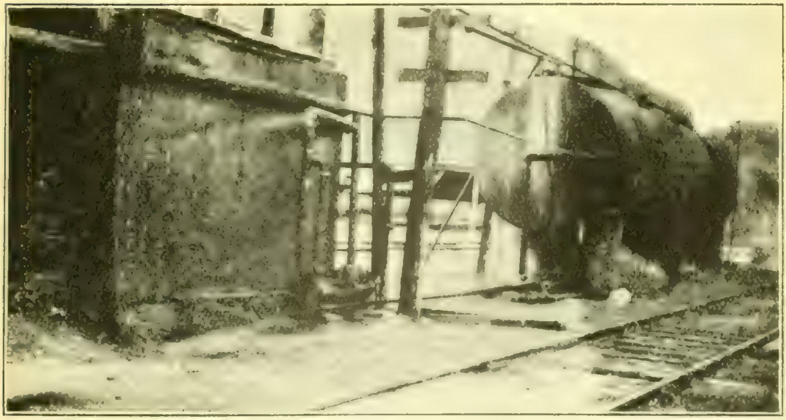
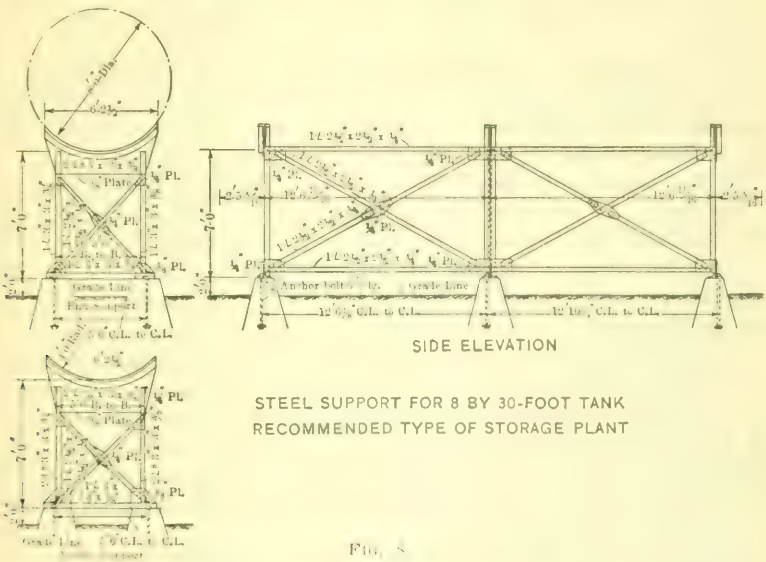


FIG. 7.—STORAGE TANK FOR OIL AND ASPHALT, ERECTED AT BOUND BROOK, N. J., BY THE GENERAL CRUSHED STONE COMPANY.

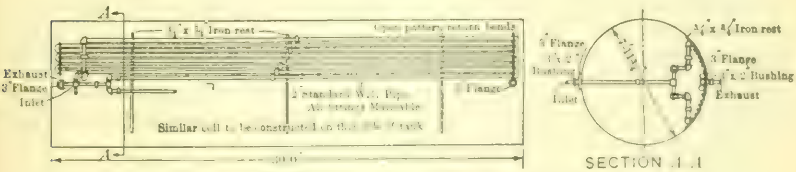
Amies Road Company.—The Amies Road Company has erected seven 12 000-gal. tanks of the type recommended, at Glen Mills and Rock Hill, Pa., Bound Brook, Millington, Great Notch, Springfield, and Lambertsville, N. J. Fig. 7 shows the tank at Bound Brook, N. J. Mr. Kershaw.

Recommended Type of Plant.—The capacity of tank-cars in the road-oil service varies from 4 000 to 12 000 gal., hence a tank 8 ft. in diameter and 30 ft. long, with an approximate capacity of 12 000 gal. is recommended.



STEEL SUPPORT FOR 8 BY 30-FOOT TANK
RECOMMENDED TYPE OF STORAGE PLANT

FIG. 8.



HEATING COIL FOR 8 BY 30-FOOT TANK
RECOMMENDED TYPE OF STORAGE PLANT

FIG. 9.

Fig. 8 shows steel supports for the tank, which are recommended as less expensive than concrete and equally efficient. Fig. 9 shows the piping arranged so that it can be put into the tank through the dome after erection, and then connected up with a series of unions. In every case the tanks should be equipped with steam coils, thus making it possible to handle any of the heavier grades of binding oils, tars, or asphalts, as well as light road oils. The cost of these coils

Mr. Kershaw.

is nominal, and as these plants are usually constructed in the city yard, where a steam plant is in operation or where a steam roller can be quickly connected, it is a profitable investment to put in the coils when the tanks are erected, even though the possibility of using them for anything but light oil cannot be foreseen. Experience has proven the merit of the following suggestions:

1. The tank should be placed so as to give a minimum fall of 2 in. in 30 ft. toward the outlet end.

2. The outlet should be placed as near as possible to one end of the tank.

3. It is important that the arrangement of steam coils in the tank should be such that a coil is placed immediately above or around the opening in the outlet pipe, thus preventing any possibility of the outlet becoming blocked by the collection of cold, solid material.

4. The steam coils should be placed on a cradle as low as possible in the tank. A maximum distance of ¾ in. between the bottom of the steam coil and the bottom of the tank is recommended.

5. When there is a possibility of using the storage tank for the handling of heavy materials late in the year, it is recommended that the outside piping be steam-jacketed.

A number of advantages accrue from the erection of storage tanks, such as the removing of all incentive to apply oil when the climatic conditions or the condition of the road surface are not favorable, and the possibility of altering the character of the oil to suit special conditions. The main reason, however, for investing in equipment of this kind is the fact that it is highly profitable and will earn a large return on the investment.

The city equipped with storage tanks immediately becomes one of the most desirable customers, and can obtain lower prices than cities not thus equipped. In the past it has not been unusual for towns using from 100 000 to 200 000 gal. of oil to pay the railroad company more than $1 000 per year in the form of demurrage, and quotations have been made in favor of the towns equipped with storage, which net a saving of from 2 to 5 mills per gal.

Mr. Fulweiler.

W. H. Fulweiler, Assoc. M. Am. Soc. C. E.—The speaker wishes to present a few notes on the practical operation of some motor sprinkling trucks during 1912. These trucks were used in applying bituminous material in what might be termed a surface penetration treatment. In other words, the endeavor was to get the material to penetrate the upper 1 in. or 1½ in. of the macadam surface, rather than to build a blanket on top of it.

In order to secure this penetration, it is essential that the surface of the road be cleaned very carefully and the larger stones composing the wearing course exposed. Even with the most careful sweeping,

it was difficult to secure a surface sufficiently free from dust to allow the uniform application of the bituminous material from gravity wagons, the material being apparently repelled by the microscopic layer of dust on the stone surface. It was evident, therefore, that some form of distributor was required from which the material would be forced under sufficient pressure directly into contact with the stone, so that the dust covering would be brushed to one side. Mr. Fulweiler

A machine of English type, manufactured by Tar Roads, Limited, London, was purchased. It was provided with a pump geared to the wheels, and by means of the reducing valve enabled a sufficient pressure to be kept on the spray lines, so that with a little care in driving the horses, quite successful results were obtained, but the weight and the small capacity of the tank precluded the use of such an apparatus where there were long hauls from the tank-cars.

With a haul of not more than 1 mile, the horse-drawn type of machine seems to work quite economically, but for a haul of more than 2½ miles, and running up to 15 or 18 miles, it is entirely out of the question.

Two 5-ton chassis, provided with 900-gal. tanks, were equipped with rotary pumps geared to the transmission, through a dog clutch, so that they could be operated when the truck was in motion or at rest. By including a pressure-reducing valve and using a speedometer, it was possible to secure a very uniform rate of distribution.

The quantity of material delivered per square yard depends on the pressure and viscosity of the material, and this, in turn, on the temperature, so that by increasing the pressure or running the truck more slowly in the morning, or during cold weather, it is possible for the driver, after a little practice, to gauge very accurately the quantity he is delivering. The pressure can be varied from 20 to 200 lb. per sq. in., and take care of any ordinary change in the viscosity, due to temperature.

The great difficulty experienced in distributing the material uniformly is mainly in hilly countries. The ordinary motor truck has not enough power to climb the various grades at the same speed, so that it is necessary to change the gear frequently, or climb a hill on a very low gear, which results in considerable loss of time. This requires the driver to do some rapid changing of the relief valves which control the pressure, and considerable experience is necessary to adjust the pressure and speed accurately and economically. It appears that not less than 80 h.p. would be required to climb average hills in the East.

Apparently, the larger the truck (and, therefore, the load), the more efficient it is, but, when operating in country districts, this is limited by the fact that the average township bridge will not carry more than 10 tons. For operation only in the city, or in districts where there is

Mr. Fulweiler. improved bridge construction, there seems to be no reason why a $6\frac{1}{2}$- or 8-ton truck might not be practicable, but 5 tons seems to be all that can be used in the country.

Another difficulty is due to the wheel base of the truck. On many country roads the shoulders will not bear the concentrated load on the rear wheels, so that it is frequently necessary to run long distances before reaching a suitable point to turn the truck. From 12 to 13 ft. seems to be the wheel base handled most economically on average roads.

In operating trucks to the maximum capacity, the greatest difficulty is due to the fact that the road is not always covered as it should be with a light coating of sand chips or gravel after the application of the material, in order to prevent it from picking up under traffic. In working from one point to another, throughout the country districts, especially about harvest time, it seems to be impossible, or at least very difficult, to secure sufficient labor to apply the covering as fast as the machine will apply the material. In a great majority of cases, the limiting factor for the truck in a day's work is the ability of the laborers to cover the material.

The use of mechanical sand distributors would probably be economical where the haul is short, but where it is from 3 to 4 miles long, it would seem that they are quite out of the question, and that the most economical method is to have the covering material spaced properly along the road side in piles, about 60 ft. apart, and then hire a gang of from 10 to 12 men and carry them from place to place with the truck to do the spreading. In this way from 2 to 3 miles of 14-ft. road can be treated daily, applying $\frac{1}{3}$ gal. of binder, and from 12 to 18 lb. of covering per sq. yd.

Mr. Johnston. J. A. Johnston, M. Am. Soc. C. E.—The first pressure-distributing machine brought into Massachusetts by the Highway Commission was not, as has been stated, one in which air pressure was pumped in over the tar, thereby forcing out the tar and oil. The air pressure was not pumped directly into the tank-wagon. The bituminous material was pumped out of the tank, and there was an air chamber attached to the pump to regulate the flow. The Aitken machine (the one referred to) gave fairly good results, but was cumbersome. It held from 1 000 to 1 200 gal., weighed 10 tons when loaded, and was mounted on rather small wheels. Much difficulty was experienced in getting it over unimproved roads in going to and from the State roads, and on many such roads it cut into the soil so deeply that two steam rollers were required to pull it through the bad places.

To overcome these difficulties the speaker devised an apparatus consisting of a steam pump mounted on a separate carriage and fastened behind an ordinary tank-wagon; it was quickly detached from an empty wagon, and re-attached to a full one. The bituminous material was

pumped from the tank-wagon and forced into the road at a pressure of not less than 70 lb. per sq. in. The working principle of the machine is a duplex steam pump with a liberal air chamber; and, to insure practically constant pressure, a release valve is set so that when the pressure exceeds 90 lb., the excess material is forced through a by-pass back into the suction. The quantity of material applied per given area is regulated principally by the rate the wagon travels over the road. There is no speedometer, but the foreman, by the aid of his watch and by counting the revolutions of the wheels, determines how fast the machine should travel. That method seems to be crude, but it has given very good results. It is difficult to calibrate such a machine, because so many factors enter the problem, namely, temperature, viscosity, and kind of material, and such items vary so widely that no set rules can be made, and much must be left to the man on the job. Mr. Johnston.

The method of doing the work is as follows: The bituminous material is shipped to the most available railroad siding in tank-cars. If the material is so heavy that it requires heating before it can be used, the tank-cars are equipped with steam coils, and a portable steam boiler is set up and connected to them for heating. If the bituminous material is tar or oil of about 90% so-called "asphaltic content," the material can be pumped from the top of the tank in about 18 hours after steam has been turned on. A steam pump attached to the boiler is used for this work, and is piped so that the bituminous material is pumped from the top of and returned to the bottom of the car, thus circulating it and overcoming any tendency to stratification. When the bituminous material has attained the proper temperature, it is pumped into tank-wagons holding about 700 gal., which are also equipped with steam coils for re-heating if necessary, and hauled with horses or traction engine to the work. These wagons, which weigh when empty about 3 000 lb., can, when loaded, be easily pulled by a single pair of horses on any ordinary road. The wagons are often jolted over rough surfaces of roads under construction, hence it has been found difficult to keep tight joints in the ordinary steam coil. This trouble has been obviated by using a special form of coil, constructed so that there are no joints within the tank. The coils are fastened securely, and no leaks can occur.

When the wagon arrives at its destination, the horses are unhitched, the wagon is coupled to the steam roller, the sprayer is then attached behind the wagon, steam connections are made to the roller, which then pulls the combination over the road and furnishes steam to drive the pump on the sprayer. The contents of the wagon can be applied on the road in an absolutely uniform coating in 20 min. When the wagon is empty, it is replaced by a full one, and the process continues while the empty tank is returned for refilling. Several tank-wagons

Mr. Johnston. are used, and, with such an equipment, 1 mile of road per day has been treated with a coating of ½ gal. per sq. yd., and covered with pea stone or gravel. Much more could be done if the grit covering could be handled to better advantage. Heating, hauling (3 miles), and applying the bituminous material by this method has been done at a cost of 1¼ cents per gal.

Motor wagons are economical for long hauls from central plants, but, up to a haul of 3 or 4 miles, they cost more to operate than the horse-drawn tank-wagon.

Mr. Blanchard. ARTHUR H. BLANCHARD, M. AM. SOC. C. E.—The selection of plant equipment for the construction and maintenance of bituminous surfaces and bituminous pavements, which will be economically suitable in methods and materials for local requirements in each case, is the keynote of successful work in this field of highway engineering.

A review of the various mixing machines, mechanical distributors, and plant accessories, and a consideration of the many kinds of mineral aggregates and types and grades of bituminous materials used in the construction of bituminous concrete and bituminous macadam pavements, demonstrate that the construction engineer and contractor should have a thorough knowledge of the limitations of each type of machine on the market. To a lesser degree, the same remarks apply to the selection of plant equipment for the construction and maintenance of bituminous surfaces.

If bituminous concrete pavements are divided into three classes, depending on the character of the mineral aggregate, that is, first, those composed of so-called, one-size, crusher-run stone, second, those composed of combinations of stone and sand, and, third, those composed of graded sizes of broken stone or broken stone and sand, it will be seen at once that some machines on the market are adaptable for only one class of pavement, and others may be used for the construction of all classes, although, in certain instances, the overhead charges connected with their operation may not render them economical. Furthermore, when the large variety of solid and semi-solid bituminous cements which may be used for the construction of bituminous pavements, is considered, it is evident that the methods of applying these materials may make it possible to use certain machines and bar others. Such details as the heating of the mineral aggregate may also be a controlling factor in the selection of mixing machines.

In the case of mechanical distributors, the quantity of material required to be applied per square yard and the type and grade of the bituminous material essentially affect the selection. It is well known that, with many distributors on the market, it is impossible to distribute certain materials which may be used satisfactorily for a surface coat, and, with others, it is found impracticable to distribute the small quantities required in some methods of construction and maintenance.

Unfortunately, sufficient investigations have not been conducted by manufacturers of mixing machines or mechanical distributors to enable them to supply all the necessary information to prospective purchasers when definite requirements are submitted to them. As a result, there are many cases of purchases of machinery unsuitable for the work in hand and of unsatisfactory results in construction and maintenance accruing therefrom. Mr. Blanchard.

J. W. Howard, Esq.—The object of spraying is to get the material down into the surface layer before it becomes chilled. That is a mechanical problem. Coal-tars when cool are stiff and brittle, hence with their products it is essential to get them in quickly, while they are liquid and warm. Anything applied by the gravity method is likely to chill and set on top. Almost all asphaltic oils retain fluidity or viscosity, even when cool, therefore, the gravity system often works well with them. Mr. Howard.

High pressures on bituminous products cause the air to enter the products and stiffen them seriously by a so-called oxidation. In the pressure system, care must be taken that the pressure is not so high that it will force air into or through the mass of warmed-up, liquid, bituminous substances, as this permanently stiffens or oxidizes them.

Philip P. Sharples, Esq.*—The speaker believes that better work can be done by some form of pressure distributor than by gravity distribution. It depends, however, on the kind of material used. Some materials work much better with pressure distribution than others on account of being more easily liquefied. With certain kinds of asphalt it would be almost impossible, in the present state of the art, for a contractor to use a pressure distributor. Mr. Sharples.

In Boston a number of Alco trucks have been fitted up with Kinney rotary pumps which deliver the tar to the spreaders at a pressure of about 30 to 35 lb. per sq. in. They, however, are better adapted to seal coats and to surface treatment than to penetration work where a large quantity per yard is called for on the first coat. It has been the practice to use the same pressure on the first penetration coat, that is, putting on about 1½ gal. of tar materials in one coat, but using steam pressure in the tank and a hand hose and spraying nozzle for the distribution. A hose in the hands of a good workman produces very good results. It is absolutely essential to have a good man at the end of the nozzle, or unequal distribution will result. The seal coat may be applied to advantage by pressure spreaders spraying ½ gal. per sq. yd.

The truck is also used on surface coatings, both with hot and cold materials, with excellent results. Auto trucks are well adapted for

* Chief Chemist, Barrett Mfg. Co., Boston, Mass.

Mr. Sharples. central plant distribution, and can cover a territory within a radius of about 60 miles. The material can be kept hot for this distance without any difficulty.

Mr. Hubbard. PREVOST HUBBARD, ASSOC. AM. SOC. C. E.—The thermometer is recognized as an important part of the necessary equipment for plant control. It is rather surprising, however, to note the number of instances where, in the construction of bituminous surfaces and bituminous pavements, the bituminous material is heated in small kettles and no attention paid to the temperature of the tar, oil, or asphalt used. Many contractors and engineers in beginning their work start with thermometers as a part of their equipment, but, as a rule, they are soon broken. The work, however, is often continued without any further attempt to keep temperature records.

The common laboratory thermometer is not satisfactory for obtaining the temperature of large quantities of bituminous material heated in kettles. It is advisable, if not necessary, when obtaining kettle temperatures to use a larger thermometer, preferably one which can be attached to the sides of the kettle and will indicate at all times the temperature of the bituminous material in the kettle. Such thermometers can be purchased at reasonable prices, and have large scales which can be read at a distance, so that the kettle man may see at all times what temperature he is maintaining. For determining the temperature of heated mineral aggregate, the average thermometer is practically useless. If it is continuously thrust into and withdrawn from hot bituminous mixes, it will eventually crack and break, due to sudden cooling.

A thermometer has been designed recently which is preferable to any other that has come to the speaker's notice. It is made by electroplating the lower 6 in. of the tube and bulb of a glass thermometer with a heavy deposit of copper, which protects the glass from abrasion, but allows quick and accurate temperature registration. The thermometer has a sharp pointed bulb, and is made of heavy glass. It reads, from 50° to 500° or 600° Fahr. This thermometer is now manufactured by the Taylor Instrument Company, after a design by Mr. J. O. Hargrove, Inspector of Asphalts and Cements, of the District of Columbia.

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FRANKLIN ALLEN HINDS, M. Am. Soc. C. E.*

DIED AUGUST 23D, 1913.

Franklin Allen Hinds was born on his father's farm near Watertown, N. Y., on November 17th, 1843, and received his elementary education in the public schools of that place. When he was 21, he went, by way of Panama, to Portland, Ore., where he studied under various engineers for two years. He then returned East, and studied for a year at Yale University.

Mr. Hinds then undertook the surveys for the Carthage, Watertown and Sacketts Harbor Railroad, and, later, was made Chief Engineer of that road. Among other railroad work of which he had charge was that for the Kingston and Pembroke, and the surveys for the New York and Boston Inland Railroad. For some years he was in partnership with Mr. John Moffett, constructing municipal water-works in all parts of the United States and Canada.

In 1889, Mr. Hinds formed a partnership with E. A. Bond, M. Am. Soc. C. E., ex-Chairman of the New York Barge Canal Advisory Board. The firm had a large consulting practice in mill construction, water-works, hydro-electric developments, and general engineering. This partnership was dissolved in 1896, but the business was continued by Mr. Hinds until his death. He was City Engineer of Watertown for several years, a member of the Board of Commissioners for 33 years, and a vestryman of Trinity Church for 26 years.

On account of his sterling character and his kindly interest in others, Mr. Hinds was always an inspiring example to the younger men with whom he came in contact. He loved his profession and instilled that love in others. To him, truth and honesty were fundamental, and no design was good, or engineering project sound, unless it was founded on truth and designed with unswerving honesty.

In 1867 he was married to Miss Mary R. Thompson, who, with one brother, Oscar E. Hinds, survives him.

Mr. Hinds was elected a Member of the American Society of Civil Engineers, on May 3d, 1899.

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* Memoir prepared by Lou B. Cleveland, Assoc. M. Am. Soc. C. E.

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On Bituminous Materials for Road Construction: W. W. Crosby, A. W. Dean, H. K. Bishop, A. H. Blanchard.

On Valuation of Public Utilities: Frederic P. Stearns, H. M. Byllesby, Thomas H. Johnson, Leonard Metcalf, Alfred Noble, William G. Raymond, Jonathan P. Snow.

To Investigate Conditions of Employment of, and Compensation of Civil Engineers: Alfred Noble, S. L. F. Deyo, Dugald C. Jackson, William V. Judson, George W. Tillson, C. F. Loweth, John A. Bensel.

To Codify Present Practice on the Bearing Value of Soils for Foundations, etc.: Robert A. Cummings, Edward C. Shankland, Edwin Duryea, Jr., James C. Meem, Walter J. Douglas, Samuel T. Wagner, Frank M. Kerr.

On a National Water Law: F. H. Newell, George G. Anderson, Charles W. Comstock, Clemens Herschel, W. C. Hoad, Robert E. Horton, John H. Lewis, Charles D. Marx, Gardner S. Williams.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thansgiving Day, and Christmas Day.

House of the Society—220 West Fifty-seventh Street, New York.

Telephone Number..........................5913 Columbus.

Cable Address......................"Ceas, New York."

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AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PROCEEDINGS

This Society is not responsible for any statement made or opinion expressed in its publications.

SOCIETY AFFAIRS

CONTENTS

MINUTES OF MEETINGS

OF THE SOCIETY

September 17th, 1913.—The meeting was called to order at 8.30 P. M.; Vice-President J. Waldo Smith in the chair; Charles Warren Hunt, Secretary; and present, also, 179 members and 29 guests.

A paper by J. C. Ulrich, M. Am. Soc. C. E., entitled "The Prewitt Reservoir Proposition", was presented by title only.

Nelson P. Lewis, M. Am. Soc. C. E., presented the report* of the representatives of the Society appointed by the Board of Direction to attend the Third International Road Congress, held at London, England, June 23d-28th, 1913, and Messrs. George W. Tillson, W. W. Crosby, D. B. Goodsell, A. H. Blanchard, and E. H. Thomes presented their personal views of and experiences at the Congress.

Adjourned.

* See page 645.

October 1st, 1913.—The meeting was called to order at 8.30 P. M.; President George F. Swain in the chair; Chas. Warren Hunt, Secretary; and present, also 157 members and 23 guests.

The minutes of the meeting of September 3d, 1913, were approved as printed in *Proceedings* for September, 1913.

A paper by William J. Wilgus, M. Am. Soc. C. E., entitled "Physical Valuation of Railroads" was presented by the author. The paper was discussed by Messrs. F. Lavis, W. W. Crehore, T. Kennard Thomson, J. Shirley Eaton, Charles S. Churchill, and the author.

The Secretary announced that written discussions on the paper by Messrs. Maurice G. Parsons, J. Frank Aldrich, J. Shirley Eaton, C. P. Howard, M. H. Brinkley, Albin G. Nicolaysen, and F. A. Molitor, had been published in the August and September numbers of *Proceedings,* and that Messrs. S. Whinery, J. E. Willoughby, Halbert P. Gillette, J. H. Gandolfo, and Alexander C. Humphreys, had also forwarded communications on the subject. Owing to lack of time Mr. Humphreys' discussion was the only one read.

The Secretary announced the election of the following candidates on October 1st, 1913:

As Members

James Ekin Allison, St. Louis, Mo.
Bert Henry Burrell, Washington, D. C.
Edwin Morris Capps, San Diego, Cal.
William Pitcher Creager, New York City
Alphonsus Ligouri Drum, Chicago, Ill.
Almon Lawrence Fales, Worcester, Mass.
Hubbard Moylan Feild, Bocas del Toro, Panama
Robinson Wilber Hawley, Berkeley, Cal.
John Albert Holmes, Mountain Mills, Vt.
Frank Elmer Lamphere, Chicago, Ill.
Charles Arthur Lindbery, Bellingham, Wash.
James William Nelson, Brooklyn, N. Y.
Floyd Odell Pease, La Paz, Bolivia
Charles Stockton Pope, Los Angeles, Cal.
George Frederick Porter, Montreal, Que., Canada
Charles Miller Reppert, Pittsburgh, Pa.
Franklin Dickinson Shaw, Philadelphia, Pa.
John Muir Sills, Springfield, Mo.
Burton Smith, Turlock, Cal.
Charles Edward Smith, St. Louis, Mo.
David Wendel Spence, College Station, Tex.
Edmund Job Steere, Providence, R. I.
Charles Eugene Sudler, Put-in-Bay, Ohio

As Associate Members

Albert Read Baker, San Rafael, Cal.
George Livingston Baker, Friendship, N. Y.
John Edward Bebb, Duluth, Minn.
Johannes Helenus Bernhard, New Orleans, La.
Harry Remington Bouton, New York City
Frederic Waterman Burnham, New York City
Alfred James Charles, Denver, Colo.
James George Esch, Cleveland, Ohio
Frank Preston Fifer, Albany, N. Y.
Francis James Fitzpatrick, Empire, Canal Zone, Panama
Howard Lewis Francis, Rocha, Uruguay
Guy Owen Fraser, Oakland, Cal.
Frank Alexander Giesting, Beristain, Puebla, Mexico
James Lawrence Harrop, Madison, Wis.
Earle Menelas Hartridge, New York City
Edward Joseph Henriques, Sioux City, Iowa
Jesse Blaine Holly, San Francisco, Cal.
Robert Hugh Houston, Rochester, N. Y.
Lyman Stanley Howe, Wilkes-Barre, Pa.
Edward Mathew Kayser, Loch Raven, Md.
Clarence Ivan Lantz, Morgantown, W. Va.
Martin Philippe Lauer, Akron, Ohio
Thomas Joseph Leahy, Denver, Colo.
Mark Linenthal, Roxbury, Mass.
Charles Winslow Lusk, Kansas City, Mo.
Charles Christopher Martin, Guayama, Porto Rico
Thomas Hatcher Matson, Las Cruces, N. Mex.
Clarence J Noland, Yonkers, N. Y.
Cuthbert Powell Noland, Jr., Baltimore, Md.
Charles William Okey, Houma, La.
James Edwin Parker, Augusta, Ga.
John Ferdinand Peterson, Cambridge, Mass.
Norman Gilman Ray, Massena, N. Y.
Charles Potter Richardson, Chicago, Ill.
Thomas Walton Roby, Jr., Kingston, Ont., Canada
Selden Emmett Rockwell, Jordan River, B. C., Canada
Samuel Joseph Sprol, Baltimore, Md.
Edwy Lycurgus Taylor, New Haven, Conn.
Clarence Lionel Todd, Pittsburgh, Pa.
Everett Franklin Tomlinson, Dorchester, Mass.
Nicholas Corneilius Vandemoer, Denver, Colo.
Conrad Meuly von Blücher, Corpus Christi, Tex.
Thomas Robert Walter, Post City, Tex.

Elwin Streeter Warner, Greenfield, Mass.
Robert Clark Wheeler, Vincennes, Ind.
Chester Greenhalgh Wigley, Trenton, N. J.
William Lane Williams, Rome, N. Y.

As Juniors

Tom Allen Bither, Berkeley, Cal.
William Blair Bovyer, San Francisco, Cal.
George Lockwood Brinkerhoff, Gatun, Canal Zone, Panama
Nicholas Colas, Puerto Barrios, Guatemala
Eugene Hunter Coleman, New Orleans, La.
Lewis Henry Delany, Greeneville, Tenn.
Carl E Downing, Belzoni, Miss.
Robert Francis Duryea, San Francisco, Cal.
Stanley Harvey Edmunds, Yankton, S. Dak.
John Fellows Gowen, Ossining, N. Y.
John Stanley Grepe, Jr., San Francisco, Cal.
James Buchanan Hays, Boise, Idaho
Solon Herzig, Butte, Mont.
Ernst Gustav Kaufmann, Toronto, Ont., Canada
Jared Leroy Mathias, San Francisco, Cal.
Laurence Minot Pitman, Arlington Heights, Mass.
Caesar Rodney Roberts, Seattle, Wash.
Valeriano Segura, Cebu, Philippine Islands
Wakeman Francis Sherwood, Binghamton, N. Y.
Leonard Hanscome Sinclair, Washington, D. C.
Ralph Smillie, New York City
William Andrew Smith, South Fork, Colo.
Frank Clyde Stewart, Kittanning, Pa.
Lawrence Johnson Williams, Seattle, Wash.

The Secretary announced the transfer of the following candidates on October 1st, 1913:

From Associate Member to Member

William Franklin Allison, Portland, Ore.
Othmar Hermann Ammann, New Brighton, N. Y.
Collingwood Bruce Brown, Jr., Montreal, Que., Canada
John Stanton Ely, Philadelphia, Pa.
Jerome Henry Fertig, Montrose, Colo.
John Blake Gordon, Washington, D. C.
Benjamin Feland Groat, Pittsburgh, Pa.
Sherman Augustus Jubb, Los Angeles, Cal.
Arnold Henry Krone, Baltimore, Md.

ARMOUR CANTRELL POLK, Clanton, Ala.
CLARENCE WEBSTER RAYNOR, Portland, Ore.
WILLIAM ERNEST SMITH, Calgary, Alberta, Canada

FROM JUNIOR TO ASSOCIATE MEMBER

JAMES EVERETT BESWICK, Albany, N. Y.
JAMES BLAINE THOMAS COLMAN, Ann Arbor, Mich.
JOHN HENRY FEIGEL, Buffalo, N. Y.
JOHN WARREN DUBOIS GOULD, New York City
JOSEPH WATSON GROSS, Sacramento, Cal.
CHARLES MACDONALD, Tarrytown, N. Y.
CHRISTOPHER GEORGE MORRISON, Lingayen, Philippine Islands
EDWIN JAMES POTTER, Pawtucket, R. I.
RALPH JOHN REED, Los Angeles, Cal.
CLIFFORD BRADLEY SUTTLE, Philadelphia, Pa.
JONATHAN ERNEST TEAL, Baltimore, Md.
NATHAN THOMAS VEATCH, JR., Kansas City, Mo.
HOMER JENNER WILKINS, Oklahoma City, Okla.

The Secretary announced the following deaths:

ARTHUR LINCOLN ADAMS, of San Francisco, Cal., elected Member, October 2d, 1895; died September 17th, 1913.

JOHN BUTLER DUNCKLEE, of South Orange, N. J., elected Member, April 2d, 1873; died July 7th, 1913.

JOHN DOUGLAS FOUQUET, of Fishkill, N. Y., elected Member, June 3d, 1885; died September 18th, 1913.

FRANCIS VALENTINE TOLDERVY LEE, of Victoria, B. C., Canada, elected Member, February 1st, 1910; died August 17th, 1913.

JAMES ROSS, of Montreal, Que., Canada, elected Member, September 6th, 1882; died September 20th, 1913.

The Secretary announced that the next meeting of the Society, on October 15th, would be held in New Orleans, La., but that arrangements were being made for holding an informal meeting at the Society House on the same date.

Adjourned.

OF THE BOARD OF DIRECTION

(Abstract)

October 1st, 1913.—President Swain in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Bush, Churchill, Edwards, Endicott, Gerber, Hodge, Ridgway, Smith, and Snow.

Thomas Coltrin Keefer, Member and Past-President, was elected by unanimous vote of the Board of Direction and of all living Past-Presidents an Honorary Member of the Society.

In the matter of the Licensing or Registration of Engineers by the various States, it was decided to keep the Committees on this subject appointed some time ago, alive, and authority was given to fill any vacancies which may have occurred, and the Secretary was instructed as soon as these Committees are filled to publish their names in *Proceedings.*

Upon request of the Committee of Management of the International Engineering Congress of 1915, the Treasurer of the Society was authorized to forward $2 250 to that Committee, this sum being 25% of the total amount underwritten by this Society, for the payment of necessary preliminary expenses.

James H. Edwards was appointed a member of the Special Committee on Steel Columns and Struts, to fill the vacancy caused by the death of the late Alfred P. Boller.

The Secretary was requested to go to San Francisco after the New Orleans Meeting to consult with, and give any aid he can to, the Committee of Management in charge of the International Engineering Congress of 1915, and also to secure as much information as possible on which to base a decision as to the time and place for holding the Annual Convention of 1915, which it has already been determined shall be held in or near San Francisco.

Ballots for membership were canvassed, resulting in the election of 23 Members, 47 Associate Members, 24 Juniors, and the transfer of 13 Juniors to the grade of Associate Member.

Twelve Associate Members were transferred to the grade of Member.

Applications were considered, and other routine business transacted.

Adjourned.

ANNOUNCEMENTS

The House of the Society is open from 9 A. M. to 10 P. M., every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

FUTURE MEETINGS

November 5th, 1913.—8.30 P. M.—This will be a regular business meeting. Two papers will be presented for discussion, as follows: "Concrete Bridges: Some Important Features in Their Design," by Walter M. Smith, Sr., M. Am. Soc. C. E., and Walter M. Smith, Jr., Jun. Am. Soc. C. E.; and "The Effect of Saturation on the Strength of Concrete," by J. L. Van Ornum, M. Am. Soc. C. E.

These papers were printed in *Proceedings* for August, 1913.

November 19th, 1913.—8.30 P. M.—At this meeting a paper by Richard R. Lyman, Assoc. M. Am. Soc. C. E., entitled "Measurement of the Flow of Streams by Approved Forms of Weirs, with New Formulas and Diagrams," will be presented for discussion.

This paper was printed in *Proceedings* for September, 1913.

December 3d, 1913.—8.30 P. M.—A regular business meeting will be held, and two papers will be presented for discussion, as follows: "Coal Piers on the Atlantic Seaboard," by J. E. Greiner, M. Am. Soc. C. E., and "Topographical Surveys Made by the American Section of the International Boundary Commission, United States and Mexico," by W. W. Follett, M. Am. Soc. C. E.

These papers are printed in this number of *Proceedings*.

SPECIAL MEETINGS FOR TOPICAL DISCUSSION

On the two days immediately following the Annual Meeting, three meetings of the Society will be held, at which the subject for discussion will be "Road Construction and Maintenance."

The meetings will be held as follows:

First Meeting, Friday, January 23d, 1914.—10 A. M.—The following sub-division of the subject will be discussed:

(1) "Engineering Organizations for Highway Work."

Second Meeting, Friday, January 23d, 1914.—2 P. M.—The following sub-division of the subject will be discussed:

(2) "Factors Limiting the Selection of Materials and of Methods in Highway Construction."

Third Meeting, Saturday, January 24th, 1914.—10 A. M.—The following sub-division of the subject will be discussed:

(3) "Equipment and Methods for Maintaining Bituminous Surfaces and Bituminous Pavements."

SPECIAL COMMITTEE ON A NATIONAL WATER LAW.

At the Society meeting of May 7th, 1913, the following was presented:

"*Moved:* That the Board of Direction of the American Society of Civil Engineers be and is hereby authorized and directed to appoint a special committee to investigate the advisability of drafting A National Water Law applicable to all navigable, interstate and other waters within the jurisdiction of the United States, and embracing all uses of water, and that such committee be directed to prepare a preliminary draft of such a law for submission at some regular meeting of the Society, if, in their judgment, it appears advisable."

This Resolution was referred to the Board of Direction.

The Board has appointed the following Committee:

F. H. Newell, *Chairman,*

George G. Anderson,
Charles W. Comstock,
Clemens Herschel,
W. C. Hoad,
Robert E. Horton,
John H. Lewis,
Charles D. Marx,
Gardner S. Williams.

LIST OF NOMINEES FOR THE OFFICES TO BE FILLED AT THE ANNUAL ELECTION, JANUARY 21st, 1914

The following list of nominees for the offices to be filled at the Annual Meeting, January 21st, 1914, received from the Nominating Committee, was presented to the Board of Direction at its meeting on September 3d, 1913. The list has already been mailed to all Corporate Members:

For President, to serve one year:

Hunter McDonald, Nashville, Tenn.

For Vice-Presidents, to serve two years:

Charles F. Loweth, Chicago, Ill.
Gardner S. Williams, Ann Arbor, Mich.

For Treasurer, to serve one year:

John F. Wallace, New York City

For Directors, to serve three years:

Arthur S. Tuttle, New York City.......District No. 1
George W. Fuller, New York City......District No. 1
Charles H. Keefer, Ottawa, Ont., Canada. District No. 2
Mortimer E. Cooley, Ann Arbor, Mich...District No. 3
Eugene E. Haskell, Ithaca, N. Y........District No. 3
Richard Montfort, Louisville, Ky.......District No. 5

REPORT OF REPRESENTATIVES OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS AT THE THIRD INTERNATIONAL ROAD CONGRESS

New York City, September 6, 1913.

To the Board of Direction of the
American Society of Civil Engineers.

Gentlemen:—We, the undersigned, having been honored by your designation as representatives of the American Society of Civil Engineers at the Third International Road Congress, which was held in London from June 23d to 28th of the present year, beg to submit the following report:

The attendance at the Congress was over 2 000, but the official figures showing the total registration are not yet available. The programme of the Congress and the subjects of the nine (9) questions and ten (10) communications submitted for consideration have been so frequently published in the engineering press that it is needless for us to enumerate them. Although they covered such subjects as the lighting of highways and vehicles, the regulation of traffic, the authorities in charge of highways, direction and distance sign posts, and the development of self-propelled vehicles, it was essentially an engineering congress. There were twenty-five (25) American authors of papers, and it is gratifying to note that, notwithstanding the fact that some of the subjects would naturally be treated by other than civil engineers, no less than seventeen (17) of the twenty-five (25) authors are members of the Society, while still other members took part in the discussions. Many of the papers presented were valuable contributions to engineering literature. The conclusions which were embodied in the resolutions adopted at the final session of the Congress contain certain fundamental principles which will doubtless be accepted by highway engineers, but a number of the resolutions submitted to the Congress by the general reporters failed of adoption or were substantially modified owing to the reluctance of many of the delegates to accept conclusions which were in any way at variance with the traditional practice with which they were familiar, and owing also to an instinctive courtesy which restrained delegates of one country from insisting upon the adoption of resolutions which did not appear to be acceptable to their colleagues from other countries. We have not embodied these resolutions in our report,* but a copy of them is attached and submitted herewith.

In connection with the Congress there was an extensive and very instructive exhibition of road machinery and materials, while the

* These resolutions are not reproduced here, but are filed in the Library of the Society where they are available for all who wish to examine them. They may also be found in *The Surveyor and Municipal and County Engineer*, July 4th, 1913.

National Physical Laboratory, including the Road Board Laboratory for the testing of road materials, was inspected by many of the delegates.

The Institution of Civil Engineers is in temporary quarters during the construction of its new building, and was, therefore, unable to place any of its rooms at the disposal of the Congress for the sectional meetings. The Institution of Mechanical Engineers and the Surveyors' Institution hospitably opened their buildings for this purpose, and one of the most delightful social functions in connection with the Congress was the reception by the Institution of Civil Engineers at Albert Hall on the evening of June 25th. The Organizing Committee arranged a number of excursions for the inspection of highways and paving plants in various parts of Great Britain, and the delegates were everywhere most hospitably entertained by the British engineers and highway officials.

The visiting members of the Society were cordially urged to attend the ceremonies incident to the unveiling of the memorial window to Lord Kelvin, at Westminster Abbey, on July 15th, but as we had to leave London before that date, we were unable to be present at the consummation of a movement in which the Society took an active part and toward the expense of which our members made substantial contribution.

The next Congress is to be held at Munich in 1916. We believe that an invitation to hold the Congress of 1919 in this country would receive favorable consideration were it not for the fact that the United States is the only important country which has not given official recognition to this movement by becoming a member of the Permanent Association of International Road Congresses, and as the Federal Congress has expressly forbidden the President to extend or accept invitations to participate in any international convention without the express authority of the Congress, it is obvious that such an invitation cannot be given.

We venture to express the hope that this prohibition will soon be repealed, that the United States Government will join with the other nations of the world in this movement, and that the highway engineers of the United States, and especially the members of this Society, may be given an opportunity to return the graceful courtesies which they have already received at the hands of the engineers and other highway officials of France, Belgium, and Great Britain, in connection with the three Road Congresses already held and which will undoubtedly be extended to them by the German officials and engineers in 1916.

Respectfully submitted,

NELSON P. LEWIS,
GEO. W. TILLSON,
W. W. CROSBY,
DANIEL B. GOODSELL,
ARTHUR H. BLANCHARD.

SEARCHES IN THE LIBRARY

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

In reference to this work, the Appendices* to the Annual Reports of the Board of Direction for the years ending December 31st, 1906, and December 31st, 1910, contain summaries of all searches made to date.

PAPERS AND DISCUSSIONS

Members and others who take part in the oral discussions of the papers presented are urged to revise their remarks promptly. Written communications from those who cannot attend the meetings should be sent in at the earliest possible date after the issue of a paper in *Proceedings*.

All papers accepted by the Publication Committee are classified by the Committee with respect to their availability for discussion at meetings.

Papers which, from their general nature, appear to be of a character suitable for oral discussion, will be published as heretofore in *Proceedings*, and set down for presentation to a future meeting of the Society, and on these, oral discussions, as well as written communications, will be solicited.

All papers which do not come under this heading, that is to say, those which from their mathematical or technical nature, in the opinion of the Committee are not adapted to oral discussion, will not be scheduled for presentation to any meeting. Such papers will be published in *Proceedings* in the same manner as those which are to

* *Proceedings*, Vol. XXXIII, p. 20 (January, 1907); Vol. XXXVII, p. 28 (January, 1911).

be presented at meetings, but written discussions, only, will be requested for subsequent publication in *Proceedings* and with the paper in the volumes of *Transactions.*

The Board of Direction has adopted rules for the preparation and presentation of papers, which will be found on page 429 of the August, 1913, *Proceedings.*

LOCAL ASSOCIATIONS OF MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

San Francisco Association

The San Francisco Association of Members of the American Society of Civil Engineers holds regular bi-monthly meetings, with banquet, and weekly informal luncheons. The former are held at 6 P. M., at the Palace Hotel, on the third Friday of February, April, June, August, October, and December, the last being the Annual Meeting of the Association.

Informal luncheons are held at 12.15 P. M. every Wednesday, and the place of meeting may be ascertained by communicating with the Secretary of the Association, E. T. Thurston, Jr., M. Am. Soc. C. E., 713 Mechanics' Institute, 57 Post Street.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in San Francisco, and any such member will be gladly welcomed as a guest.

Colorado Association

The meetings of the Colorado Association of Members of the American Society of Civil Engineers are held on the second Saturday of each month, except July and August. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary, Roger W. Toll, Jun. Am. Soc. C. E., 700 Tramway Building, Denver, Colo. The meetings are usually preceded by an informal dinner. Members of the American Society of Civil Engineers will be welcomed at these meetings.

Weekly luncheons are held on Wednesdays, and, until further notice, will take place at the Colorado Traffic Club.

Visiting members are urged to attend the meetings and luncheons.

(Abstract of Minutes of Meeting)

September 13th, 1913.—The meeting was called to order; President Ridgway in the chair; Roger W. Toll, Secretary; and present, also, 10 members and 2 guests.

The minutes of the meeting of June 14th, 1913, the Annual Meeting, were read and approved.

The resignation of G. N. Houston, M. Am. Soc. C. E., as President of the Association, was read, and the announcement was made that, in accordance with the Constitution, Vice-President Ridgway had succeeded to the office of President and that the Executive Committee had chosen E. F. Vincent, M. Am. Soc. C. E., to fill the office of Vice-

President. On motion the action of the Executive Committee in this matter was adopted.

The report of the Auditing Committee was read and adopted.

In accordance with a resolution, the President appointed Messrs. H. S. Crocker, Chairman, John E. Field, and Robert Follansbee, a Committee to take action in regard to a contribution to the International Engineering Congress.

A paper by M. C. Hinderlider, M. Am. Soc. C. E., entitled "The Santa Cruz Valley Irrigation Project at Tucson, Arizona," was presented by the author who illustrated his remarks with stereopticon views.

Adjourned.

Atlanta Association

(Abstract of Minutes of Meeting)

September 12th, 1913.—At a meeting held at the Carnegie Library, President Arthur Pew in the chair; James Nisbet Hazlehurst, Chairman of the Executive Committee, acting as Secretary; the following business was transacted:

The Report of the Executive Committee relative to a movement toward affiliating with the Local Chapters of other Scientific Societies represented in the City of Atlanta, was presented and discussed. On motion, the action of the Executive Committee in this matter was approved, and the acceptance, on the part of the Association, of membership in the proposed general organization of local chapters, was carried, provided the project received the approval of the Board of Direction of the American Society of Civil Engineers.

B. M. Hall, M. Am. Soc. C. E., was appointed a member of the Executive Committee to serve out the unexpired term of Alexander Bonnyman, M. Am. Soc. C. E., whose resignation was accepted on account of change of residence.

At the request of the Carnegie Library Commission, President Pew appointed Messrs. Hall, Dallis, and Thayer to act as an Advisory Committee in the selection of such technical literature as the Commission shall hereafter purchase for the Library.

On motion, Mr. Hazlehurst was selected to represent the Association in the future affairs of the Affiliated Technical Societies of the City of Atlanta, and to serve on its Executive Committee until his successor is appointed.

Adjourned.

Philadelphia Association

At its meeting of June 4th, 1913, the Board of Direction of the Society considered and approved the proposed Constitution of the Philadelphia Association of Members of the American Society of Civil Engineers.

Portland, Ore., Association

On June 18th, 1913, the Portland, Ore., Association of Members of the American Society of Civil Engineers was organized with the following officers: E. G. Hopson, President; W. S. Turner, First Vice-

President; D. D. Clarke, Second Vice-President; G. B. Hegardt, Treasurer; and Charles J. McGonigle, Secretary.

Seattle Association

On June 30th, 1913, the Seattle Association of Members of the American Society of Civil Engineers was organized with the following officers: Samuel H. Hedges, President; Ernest B. Hussey, Vice-President; and Joseph Jacobs, Secretary-Treasurer.

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms, and at all meetings:

American Institute of Mining Engineers, 29 West Thirty-ninth Street, New York City.

American Society of Mechanical Engineers, 29 West Thirty-ninth Street, New York City.

Architekten-Verein zu Berlin, Wilhelmstrasse 92, Berlin W. 66, Germany.

Associação dos Engenheiros Civis Portuguezes, Lisbon, Portugal.

Australasian Institute of Mining Engineers, Melbourne, Victoria, Australia.

Boston Society of Civil Engineers, 715 Tremont Temple, Boston, Mass.

Brooklyn Engineers' Club, 117 Remsen Street, Brooklyn, N. Y.

Canadian Society of Civil Engineers, 413 Dorchester Street, West, Montreal, Que., Canada.

Civil Engineers' Society of St. Paul, St. Paul, Minn.

Cleveland Engineering Society, Chamber of Commerce Building, Cleveland, Ohio.

Cleveland Institute of Engineers, Middlesbrough, England.

Dansk Ingeniorforening, Amaliegade 38, Copenhagen, Denmark.

Engineers' and Architects' Club of Louisville, Ky., 303 Norton Building, Fourth and Jefferson Streets, Louisville, Ky.

Engineers' Club of Baltimore, Baltimore, Md.

Engineers' Club of Minneapolis, 17 South Sixth Street, Minneapolis, Minn.

Engineers' Club of Philadelphia, 1317 Spruce Street, Philadelphia, Pa.

Engineers' Club of St. Louis, 3817 Olive Street, St. Louis, Mo.

Engineers' Club of Toronto, 96 King Street, West, Toronto, Ont., Canada.

Engineers' Society of Northeastern Pennsylvania, 302 Board of Trade Building, Scranton, Pa.

Engineers' Society of Pennsylvania, 219 Market Street, Harrisburg, Pa.

Engineers' Society of Western Pennsylvania, 2511 Oliver Building, Pittsburgh, Pa.

Institute of Marine Engineers, 58 Romford Road, Stratford, London, E., England.

Institution of Engineers of the River Plate, Buenos Aires, Argentine Republic.

Institution of Naval Architects, 5 Adelphi Terrace, London, W. C., England.

Junior Institution of Engineers, 39 Victoria Street, Westminster, S. W., London, England.

Koninklijk Instituut van Ingenieurs, The Hague, The Netherlands.

Louisiana Engineering Society, 321 Hibernia Bank Building, New Orleans, La.

Memphis Engineering Society, Memphis, Tenn.

Midland Institute of Mining, Civil and Mechanical Engineers, Sheffield, England.

Montana Society of Engineers, Butte, Mont.

North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne, England.

Oesterreichischer Ingenieur- und Architekten-Verein, Eschenbachgasse 9, Vienna, Austria.

Pacific Northwest Society of Engineers, 803 Central Building, Seattle, Wash.

Rochester Engineering Society, Rochester, N. Y.

Sachsischer Ingenieur- und Architekten-Verein, Dresden, Germany.

Sociedad Colombiana de Ingenieros, Bogota, Colombia.

Sociedad de Ingenieros del Peru, Lima, Peru.

Societe des Ingenieurs Civils de France, 19 Rue Blanche, Paris, France.

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DONATIONS*

CONSERVATION OF WATER.

By Walter McCulloh, M. Am. Soc. C. E. Cloth, 10 x 7 in., illus., 10 + 99 pp. New Haven, Yale University Press; London, Humphrey Milford, Oxford University Press, 1913. $2.00.

In a secondary title, it is stated that this book consists of addresses on the subject of water conservation delivered in the Chester S. Lyman Lecture Series, 1912, before the Senior Class of the Sheffield Scientific School of Yale University, this volume constituting the first of that series of lectures. The principal problems discussed by the author in these lectures are stated to be the regulation of rivers, the control and prevention of floods, and the proper authorities for effecting such control and regulation. In the course of the discussion, he presents the questions involved in the solution of these problems, the proposed methods of procedure suggested by the study of the subject, the benefits to be derived by individuals, municipalities, etc., from the proper regulation of streams, and, in his last lecture, he uses what has been done with the water resources of New York State as an example of what can or might be done to accomplish water conservation. The Contents are: Introductory; Basic Data Essential to a Comprehensive Study of Water Storage; Water Power; Water Storage for Water Supplies, Sanitation, and Irrigation; Water Resources of New York State.

TEXT-BOOK ON HIGHWAY ENGINEERING.

By Arthur H. Blanchard, M. Am. Soc. C. E., and Henry B. Drowne, Assoc. M. Am. Soc. C. E. Cloth, $9\frac{1}{4}$ x $6\frac{1}{4}$ in., illus., 13 + 762 pp. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Limited, 1913. $4.50. (Donated by the Authors and Publishers.)

The subject-matter of this book, it is stated, is based largely on lectures prepared by the authors for their various classes and on their practice, as highway engineers, in the United States, Canada, and Europe. All phases of modern highway engineering are said to have been treated, and there are chapters on such subjects as Preliminary Investigations, Surveying and Mapping, Economics, Administration, and Legislation, which are thought to be somewhat of an innovation in books on this subject. Bituminous materials and their use in the construction and maintenance of roads and pavements are discussed in detail, and numerous references are made in the text to the writings of eminent engineers and chemists on the subject. Standard specifications and reports of various National Societies have also been quoted, in order, the preface states, that practice throughout the United States rather than that of an individual or a given locality, may be represented. The book has been written, it is stated, primarily from the standpoint of the instructor and student, with a logical order and arrangement of the subject-matter and sufficient detail to acquaint the student with the principles and practice of modern highway engineering; its scope, however, is stated to be sufficiently broad, in reference to materials, construction, maintenance, specifications, and cost data to serve as a comprehensive reference book on highway engineering for the practicing engineer. The Contents are: Historical Review; Preliminary Investigations; Surveying and Mapping; Design; Drainage; Foundations; Earth and Sand-Clay Roads; Gravel Roads; Broken Stone Roads; Bituminous Materials; Dust Prevention by the Use of Palliatives; Bituminous Surfaces; Bituminous Gravel and Bituminous Macadam Pavements; Bituminous Concrete Pavements; Sheet Asphalt and Rock Asphalt Pavements; Wood Block Pavements; Stone Block Pavements; Brick Pavements; Concrete Pavements; Miscellaneous Roads and Pavements; Street Cleaning and Snow Removal; Car Tracks; Pipe Systems; Comparison of Roads and Pavements; Sidewalks, Curbs, and Gutters; Bridges, Culverts, and Guard Rails; Economics, Administration, and Legislation; Index.

AN ELEMENTARY TREATISE ON CALCULUS:

A Text Book for Colleges and Technical Schools. By William S. Franklin, Barry MacNutt, and Rollin L. Charles. Cloth, $8\frac{1}{4}$ x 6 in., illus., 9 + 253 + 41 pp. South Bethlehem, Pa., Published by the Authors, 1913. $2.00.

In order to lead to a clear understanding of the principles of calculus, the authors' chief endeavor, it is stated, has been to develop the subject as simply and

* Unless otherwise specified, books in this list have been donated by the publishers.

directly as possible, to which end they have given a number of formal problems in differentiation and integration. The authors believe that it is a mistake in a text-book on calculus to break the thread of the textual discussion by inserting algebraic problems, and therefore have included their formal problems in Appendices A and B, and, in Appendix C, they have given a selected list of treatises on mathematics and mathematical physics, references to many of which are made in the text. The fact that the infinitesimal method tends greatly to directness and simplicity in the discussion of physical problems, has led the authors, it is stated, to use the idea of infinitesimals throughout their text. The Chapter headings are: A General Survey of Differential and Integral Calculus; Formulas for Differentiation and Integration; Integration; Partial Differentiation and Integration; Miscellaneous Applications of Calculus; Expansions in Series; Some Ordinary Differential Equations; The Partial Differential Equation of Wave Motion; Vector Analysis; Appendix A, Problems; Appendix B, Table of Integrals; Appendix C, Some Important Books on Mathematical Theory; Index.

LABORATORY MANUAL OF TESTING MATERIALS.

By William Kendrick Hatt, M. Am. Soc. C. E., and H. H. Scofield. Cloth, $7\frac{3}{4}$ x $5\frac{1}{4}$, illus., 9 + 135 pp. New York and London, McGraw-Hill Book Company, Inc., 1913. $1.25.

This manual, it is stated, is the outcome of eighteen years' experience in the Laboratory for Testing Materials at Purdue University. As now issued it has been considerably enlarged, the list of experiments has been increased, and a more complete treatment of machines and apparatus has been added. The subject-matter relates to definitions, methods, apparatus, experiments, etc., which may be used in any testing laboratory, and it is hoped, the preface states, that practitioners, as well as students, will find the volume useful in relation to their work in engineering design and inspection of materials. One of the purposes of the manual, as stated, is to relieve the instructor of the necessity of explaining the details of mechanical procedure. The Chapter headings are: General; General Instructions; Definitions; Materials Stressed Beyond the Elastic Limit; Testing and Testing Machines; List of Experiments; Instructions for Performing Experiments; Appendix I, Common Formulas; Appendix II, Strength Specifications for Steel and Iron; Appendix III, Standard Forms of Test Pieces; Strength Tables; Index.

THE CONTROL OF WATER

As Applied to Irrigation, Power and Town Water Supply Purposes. By Philip A. Morley Parker, Assoc. M. Am. Soc. C. E. Cloth, 9 x 6 in., illus., 1055 pp. London, George Routledge & Sons, Limited, 1913. (Donated by the Author.)

The subject-matter contained in this book, it is stated, is the result of actual engineering experience, being based for the most part on notes and formulas gathered by the author during eighteen years or more of professional practice, and he, therefore, hopes that it will be used as a manual by engineers in actual work. As stated in the title the work relates to a study of hydraulics as applied to irrigation and water supply, and includes detailed discussion of both the theoretical and practical sides of the subject. Numerous formulas, tables, and illustrations are included, and, wherever possible, references to original authorities are given. The Contents are: Preliminary Data; General Theory of Hydraulics; Gauging of Streams and Rivers; Gauging by Weirs; Discharge of Orifices; Collection of Water and Flood Discharge; Dams and Reservoirs; Pipes; Open Channels; Filtration and Purification of Water; Problems Connected with Town Water Supply; Irrigation; Movable Dams; Hydraulic Machinery Other Than Turbines; Turbines and Centrifugal Pumps; Concrete, Ironwork, and Allied Hydraulic Construction; Tables; Graphic Diagrams; Index.

SAFETY FIRST.

By George Bradshaw. Paper, $7\frac{1}{2}$ x 5 in., illus., 130 pp. New York and London, McGraw-Hill Book Company, Inc., 1913. 50 cents.

In the Introduction, it is stated that the officials and employés of railroads and industrial corporations are engaged in a campaign for greater safety in operation and for the prevention of injuries. The author's aim in this work has been to contribute to the advancement of this campaign by calling the attention of the employés of these corporations to views of safe and unsafe practices and conditions which occur in the course of their routine duties, with proper comments thereon, in the hope that they will study them carefully and learn to apply them in their work.

A TREATISE ON ROADS AND PAVEMENTS.

By Ira Osborn Baker, M. Am. Soc. C. E. Second Edition, Enlarged. Cloth, $9\frac{1}{4}$ x 6 in., illus., 11 + 698 pp. New York, John Wiley & Sons, Inc., London, Chapman & Hall, Limited, 1913. $5.00.

The purpose of this new edition, it is stated, is to add to the book, a chapter on Automobile Roads and Concrete Pavements, which has been made necessary by the number and power of modern automobiles, and the consequent development of new forms of road surfaces designed to resist motor traffic. The continued development of the Portland cement industry has led to the introduction of a new type of concrete road surface which is also discussed in this chapter. In the preface to the first edition, issued in 1903, it is stated that the author's object is a discussion, from the engineer's viewpoint, of the principles involved in the construction of country roads and city pavements, as the science of road-making and maintenance is based on well-established elementary principles, on the correct reasoning of which, rather than on rules and methods of construction, such art depends. The first four chapters of the book relate to the economics and location of country roads and to the construction and location of earth roads. The other chapters relate to the construction and maintenance of hard roads and pavements, and are based on American principles of road-making as being best suited to American conditions. The Contents are: Part I, Country Roads: Road Economics; Road Location; Earth Roads; Gravel Roads; Broken-Stone Roads; Miscellaneous Roads; Equestrian Roads and Horse-Race Tracks. Part II, Street Pavements: Pavement Economics; Street Design; Street Drainage; Curbs and Gutters; Pavement Foundations; Asphalt Pavements; Brick Pavements; Cobble-Stone Pavement; Stone-Block Pavement; Wood-Block Pavements; Comparison of Pavements; Sidewalks; Bicycle Paths and Race Tracks; Automobile Roads and Concrete Pavements; Index.

HYDRAULIC TURBINES

With a Chapter on Centrifugal Pumps. By R. L. Daugherty. Cloth, $9\frac{1}{2}$ x $6\frac{1}{4}$ in., illus., 9 + 156 pp. New York and London, McGraw-Hill Book Company, Inc., 1913. $2.00.

The preface states that the design of hydraulic turbines is a highly specialized industry, few engineers being called on at present to design such machines. With the increasing use of water power, however, many engineers and designers, it is stated, will find it necessary to familiarize themselves with the construction details of turbines, their characteristics, and the type and size of machine for any given set of conditions, and the author hopes that to such men, a clear understanding of the theory, as here presented, will be of interest. The purpose of the book, it is stated, is to give the student and the engineer a general idea of water-power development and the conditions affecting turbine operation; a knowledge of the principal features of modern turbine construction; an outline of the theory and characteristics of the principal types, commercial constants, selection of type and size of turbine, costs, water power, and the cost of the latter as compared with steam power. Water-power development is treated only as it relates to the choice of turbines, such related subjects as stream gauging and rating, rainfall, run-off, etc., being treated briefly. The Chapter headings are: Introduction; Types of Turbines and Settings; Water Power; The Tangential Water Wheel; The Reaction Turbine; General Theory; Theory of the Tangential Water Wheel; Theory of the Reaction Turbine; Turbine Testing; General Laws and Constants; Selection of a Turbine; Selection of Type of Turbine; Cost of Turbines and Water Power; Centrifugal Pumps; Index.

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The Theory of Sound. By John William Strutt, *Baron* Rayleigh. 2 Vol. Second Edition, Revised and Enlarged. Macmillan and Co., London and New York, 1894.

The Scientific American Cyclopedia of Formulas, Partly Based Upon the Twenty-eighth Edition of Scientific American Cyclopedia of Receipts, Notes and Queries. Edited by Albert A. Hopkins. Munn & Co., Inc., New York, 1913.

Scientific American Reference Book, Edition of 1913. Compiled and Edited by Albert A. Hopkins and A. Russell Bond. Munn & Co., Inc., New York, 1913.

Coast Erosion and Protection. By Ernest R. Matthews. J. B. Lippincott Co., Philadelphia; Charles Griffin & Co., Ltd., London, 1913.

The Calorific Power of Fuels, With a Collection of Auxiliary Tables and Tables Showing the Heat of Combustion of Fuels, Solid, Liquid, and Gaseous; to Which is Appended the Report of the Committee on Boiler Tests of the American Society of Mechanical Engineers (December, 1899). By Herman Poole. Second Edition, Revised and Enlarged. John Wiley & Sons, New York; Chapman & Hall, Ltd., London, 1910.

Investigations and Experimental Researches for the Construction of My Large-Oil-Engine: Paper read before the Schiffbautechnische Gesellschaft at Berlin, November 24th, 1911. By H. Junkers. Verlag für Fachliteratur G. m. b. H., London, Berlin, Wien.

Reinforced Concrete Bridges. By Frederick Rings. D. Van Nostrand Co., New York, 1913.

Public Utilities, Their Cost New and Depreciation. By Hammond V. Hayes. D. Van Nostrand Co., New York, 1913.

Natural Rock Asphalts and Bitumens: Their Geology, History, Properties and Industrial Application. By Arthur Danby. D. Van Nostrand Co., New York, 1913.

Factory Lighting. By Clarence E. Clewell. McGraw-Hill Book Co., New York and London, 1913.

Engineering Thermodynamics. By Charles Edward Lucke. McGraw-Hill Book Co., New York and London, 1912.

General Metallurgy. By H. O. Hofman. McGraw-Hill Book Co., New York and London, 1913.

Die Kanalisation der Freien und Hansestadt Hamburg. Bearbeitet im Auftrage der Baudeputation von Curt Merckel. Boysen & Maasch, Hamburg, 1910.

Diamantbohrungen für Schürf- und Aufschlussarbeiten über und unter Tage. Von Georg Glockemeier. Julius Springer, Berlin, 1913.

American Society for Testing Materials: Index to Proceedings. Vol. 1-12 (1898-1912.) Edited by the Secretary. Published by the Society, Philadelphia, 1913.

Elements of Water Bacteriology with Special Reference to Sanitary Water Analysis. By Samuel Cate Prescott and Charles Edward Amory Winslow. Third Edition, Rewritten. John Wiley & Sons, Inc., New York: Chapman & Hall, Limited, London, 1913.

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ESPY, THOMAS WILLARD. Asst. Engr., Spring Val. Water Co., 375 Sutter St., San Francisco, Cal		Sept. 3, 1913
FITTING, HAROLD HANSEN. Office Engr., Duryea, Haehl & Gilman, 1318 Humboldt Bank Bldg., San Francisco, Cal	Jun. Assoc. M.	May 2, 1911 Sept. 3, 1913
FLOYD, OZRO NOWLIN. With Morgan Eng. Co., City National Bank Bldg., Dayton, Ohio		Sept. 3, 1913
FREELAND, FRANCIS EUGENE. Chf. Draftsman, Nashville Bridge Co., 65 Life and Casualty Bldg., Nashville, Tenn		Sept. 3, 1913
HEWES, FLOYD SINNOCK. Asst. Engr., Constr., A., T. & S. F. Ry., P. O. Box 66, Winslow, Ariz		Sept. 3, 1913
HOFFMAN, LUTHER ROMBERGER. Structural Engr., Smith, Hinchman & Grylls, 700 Washington Arcade, Detroit, Mich		Sept. 3, 1913
HURLBUT, WILLIAM WHITEHEAD. Chf. Draftsman, Los Angeles Aqueduct, 636 South Hill St., Los Angeles, Cal		Sept. 3, 1913
KITTREDGE, FRANK ALVAH. Medford, Ore	Jun. Assoc. M.	Mar. 1, 1910 Sept. 3, 1913
KLUG, LEBRECHT JULIUS. Cons. Engr., Room 40, Mack Blk., Milwaukee, Wis		Sept. 3, 1913
KNOUSE, HOMER VIRGIL. Civ. Engr., Colorado-Yule Marble Co., Crystal River & San Juan R. R., and Town of Marble, Marble, Colo		May 7, 1913
LAWRENCE, EGBERT VANHORN. Asst. Engr., Bureau of Highways, Bronx, 1718 Edison Ave., New York City.		Sept. 3, 1913

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LIGHTNER, GEORGE W CASS. Asst. Engr., Structural Dept., G. T. Ry. System, Office of Chf. Engr., Montreal, Que., Canada	Jun. Assoc. M.	Feb. 28, 1911 Sept. 3, 1913
MCCLEAN, GEORGE THOMAS. Junior Engr., U. S. Engr. Office, Fort Stevens, Ore		Sept. 3, 1913
MCDANIEL, GEORGE GLENN. Mills Bldg., San Francisco, Cal	Jun. Assoc. M.	Mar. 5, 1907 April 2, 1913
MCWETHY, LEROY. Bridge Insp. and Asst. Engr., N. W. Pac. R. R., 912 Phelan Bldg., San Francisco, Cal	Jun. Assoc. M.	Jan. 4, 1910 Sept. 3, 1913
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MILLER, HUGH. Prof. of Civ. Eng., Clarkson School of Technology; Cons. Engr., 1 Chestnut St., Potsdam, N. Y	Jun. Assoc. M.	Nov. 30, 1909 June 4, 1913
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REEVE, LEROY NORMAN. Asst. Engr., U. S. Reclamation Service, Arrowrock, Idaho		Sept. 3, 1913
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WILSON, JAMES. State Highway Commr.; County Rd. Engr., New Castle County, Montchanin, Del.	Sept. 3, 1913
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JUNIORS

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CLARKE, ALFRED HENRY. 60 Fenway, Boston, Mass.	Sept. 3, 1913
COLLINS, MERTON CLYDE. Structural Engr., Bureau of Architecture, 473 Sanchez St., San Francisco, Cal.	Sept. 3, 1913
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GREGORY, WHITNEY IRWIN. Junior Engr., U. S. Engr. Dept., P. O. Box 72, Louisville, Ky.	Sept. 3, 1913
HIRZEL, ALFRED SPARKS. Asst. City Engr., 1319 Shallcross Ave., Wilmington, Del.	Sept. 3, 1913
HITT, HENRY COLLINS. Care, State Highway Commr., Olympia, Wash.	Sept. 3, 1913
HOLT, ANDREW HALL. Instr. in Civ. Eng., Univ. of Vermont, 30 North Winooski Ave., Burlington, Vt.	Sept. 3, 1913
LEE, FRANK OSBORNE. 30 North Winooski Ave., Burlington, Vt.	Sept. 3, 1913
MARKS, EDWIN HALL. First Lieut., Corps of Engrs., U. S. A., Washington Barracks, Washington, D. C.	Sept. 3, 1913
SANDSTEDT, CARL EDWARD. Spangle, Wash.	June 4, 1913
SAWYER, ERNEST WALKER. Newcastle, N. B., Canada	May 7, 1913
STEWART, JAMES ROBERT. 2000 Summit St., Kansas City, Mo.	July 2, 1913

JUNIORS (*Continued*)

	Date of Membership.
WAY, WILLIAM FLOYD. Draftsman, Stone & Webster Constr. Co., Fresno, Cal	Sept. 3, 1913
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REINSTATEMENT

ASSOCIATE MEMBER

	Date of Reinstatement.
Scott, John Kuhn	Sept. 3, 1913

RESIGNATIONS

MEMBERS

	Date of Resignation.
Peary, Robert Edwin	Sept. 3, 1913
Richards, Joseph Thomas	Sept. 3, 1913

ASSOCIATE MEMBER

Stanage, John Lynch	Sept 3, 1913

DEATHS

Adams, Arthur Lincoln. Elected Member, October 2d, 1895; died September 17th, 1913.

Duncklee, John Butler. Elected Member, April 2d, 1873; died July 7th, 1913.

Fouquet, John Douglas. Elected Member, June 3d, 1885; died September 18th, 1913.

Lee, Francis Valentine Toldervy. Elected Member, February 1st, 1910; died August 17th, 1913.

Ross, James. Elected Member, September 6th, 1882; died September 20th, 1913.

Total Membership of the Society, October 2d, 1913, 7 143.

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(September 2d to October 1st, 1913)

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In the subjoined list of articles, references are given by the number prefixed to each journal in this list:

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(2) *Proceedings,* Engrs. Club of Phila., Philadelphia, Pa.
(3) *Journal,* Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal,* Western Soc. of Engrs., Chicago, Ill., 50c.
(5) *Transactions,* Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly,* Columbia Univ., New York City, 50c.
(7) *Gesundheits Ingenieur,* München, Germany.
(8) *Stevens Institute Indicator,* Hoboken, N. J., 50c.
(9) *Engineering Magazine,* New York City, 25c.
(10) *Cassier's Magazine,* New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News,* New York City, 15c.
(14) *Engineering Record,* New York City, 10c.
(15) *Railway Age Gazette,* New York City, 15c.
(16) *Engineering and Mining Journal,* New York City, 15c.
(17) *Electric Railway Journal,* New York City, 10c.
(18) *Railway and Engineering Review,* Chicago, Ill., 15c.
(19) *Scientific American Supplement,* New York City, 10c.
(20) *Iron Age,* New York City, 20c.
(21) *Railway Engineer,* London, England, 1s. 2d.
(22) *Iron and Coal Trades Review,* London, England, 6d.
(23) *Railway Gazette,* London, England, 6d.
(24) *American Gas Light Journal,* New York City, 10c.
(25) *Railway Age Gazette,* Mechanical Edition, New York City, 20c.
(26) *Electrical Review,* London, England, 4d.
(27) *Electrical World,* New York City, 10c.
(28) *Journal,* New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal,* Royal Society of Arts, London, England, 6d.
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A Method of Improving the Quality of Arsenical Copper.* F. Johnson. (Paper read before the Inst. of Metals.) (11) Sept. 5; (47) Sept. 19.
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Lead-Refining Plant at Omaha, Neb.* H. B. Pulsifer. (82) Sept. 13.
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Metal Mining.* Ervin W. McCullough. (Paper read before the Civil Engrs.' Soc. of St. Paul.) (1) Sept.
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Electrical Distribution for Mines. J. W. Anson. (Abstract of paper read before the South African Inst. of Elec. Engrs.) (22) Sept. 5.
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Safety in the Mines of the Iron Ranges. Edwin Higgins. (Abstract of paper read before the Lake Superior Min. Inst.) (82) Sept. 13.
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Factors Affecting Choice of Mining Method. E. M. Weston. (16) Sept. 20.
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Mining Methods on the Mesabi Range.* (Report of Committee of Lake Superior Min. Inst.) (82) Sept. 27; (16) Sept. 27.

Miscellaneous.

The Present Opportunities and Consequent Responsibilities of the Engineer. Alexander C. Humphreys. (55) Vol. 34.
Axioms Concerning Manufacturing Costs. Henry R. Towne. (55) Vol. 34.
The Present State of the Art of Industrial Management.* (Majority and Minority Reports of Sub-Committee, Am. Soc. Mech. Engrs. on Administration.) (55) Vol. 34.
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Home Experiments in Illumination from Large-Area Light Sources.* Herbert E. Ives. (Paper read before the Phila. Section of the Illuminating Eng. Soc. of New York.) (66) Sept. 2.
The Two Epochs of Rate Regulation. William J. Norton. (Paper read before the National Elec. Light Assoc.) (86) Sept. 10.
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The Pennsylvania Public Service Company Law. (24) Sept. 15.

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The Birmingham Town Planning Schemes and Notes on the Procedure Regulations.* Henry E. Stilgoe, M. Inst. C. E. (Paper read before the Institution of Mun. and County Engrs.) (104) Serial beginning Aug. 29.
Causes of Wear and Deterioration of Roadways. Laurence J. Hewes. (Paper read before the Permanent Inter. Assoc. of Road Congresses.) (13) Sept.
Why Some Municipal Asphalt Plants Fail. H. B. Pullar. (60) Sept.
Petrolitic Road Construction, with Costs of Construction and Maintenance.* K. F. Postle. (60) Sept.
Macadam Road Construction Statistics. John McNeal, M. Am. Soc. C. E. (60) Sept.
Cost and Value of Road Materials. John H. Mullen. (60) Sept.
The New Home Rule Charter of Dayton, Ohio. (60) Sept.
The Patch System of Road Maintenance. Zdensko Vytvan. (Paper read before the Third Inter. Road Congress.) (86) Sept. 3.
Machine Rammers for Compacting Broken Stone. C. Guillet. (Paper read before the Third Inter. Road Congress.) (86) Sept. 3.
Wood Block Pavements in Australia. A. C. Mountain. (Paper read before the Third Inter. Road Congress.) (86) Sept. 3.
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Organization of the Street Department of St. Louis, Mo. James C. Travilla. (Paper read before the Third Inter. Road Congress.) (86) Sept. 17.
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Concrete Road Construction. A. N. Johnson. (Abstract of paper read before the Permanent Inter. Assoc. of Road Congresses.) (13) Sept. 25.
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Electric Locomotives for Main Line and Suburban Services.* B. Parker Haigh. (Paper read before the Scientific Soc. of the Royal Technical College, Glasgow.) (47) Serial beginning Aug. 29.
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A Consideration of British Express Locomotive Design. E. A. Johnston. (12) Serial beginning Aug. 29.
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Advantages of the Brick Arch.* Le Grand Parish. (Paper read before the Traveling Engrs.' Assoc.) (25) Sept.
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Notes on the Prevention of Iron Corrosion. W. F. Monfort. (Paper read before the Am. Public Health Assoc.) (86) Sept. 17.
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*Illustrated.

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COAL PIERS ON THE ATLANTIC SEABOARD.

By J. E. Greiner, M. Am. Soc. C. E.

To be Presented December 3d, 1913.

Scope of the Investigation.

On the Atlantic Seaboard from Maine to Florida there are four harbors which contain ports of importance where coal is discharged directly from commercial coal piers into the hatches of vessels. These harbors are New York, Philadelphia, Baltimore, and Norfolk.

There are 13 ports, embracing 29 coaling plants, in New York Harbor;
3 " " 11 " " " operation and 2 under construction in Philadelphia Harbor;
4 ports, embracing 8 coaling plants, in Baltimore Harbor;
3 " " 8 " " " operation and 2 under construction in Norfolk Harbor;

making a total of 23 ports, embracing 56 plants in operation and 4 under construction. In addition, the construction of new plants at Baltimore, Philadelphia, and New York, is under consideration at the present time.

During the summer of 1912 the writer was retained to report on the facilities of these plants. With the assistance of his staff, each

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

plant was examined, and investigations were made concerning its output, capacity, cargoes, type, tracks, grades, equipment, construction, and operation. With the consent of his client, the writer submits the substance of his investigations, with the hope that the information collated will be of interest to the members of the Society and of value to those concerned in the delivery of coal to vessels.

TABLE 1.—Data Concerning

Railway or operator.	Location.	Type.
Eastern Coal Co. (P. R. R)	South Amboy, N. J	Loco. Incline A4
" " "	"	McMyler B2
" " "	"	" B2
" " "	"	Grade A2
L. V. R. R	Perth Amboy, N. J	Grade and Gravity A3
"	"	" " A3
P. & R. Ry	Port Reading, N. J	Loco. Incline A4
"	"	" " A6
"	"	" " A6
C. R. R. of N. J	Elizabeth Port, N. J	" " A4
" "	"	" " A4
" "	"	" " A4
Wilkesbarre C. Co. (C. R. R. of N. J.)	Port Johnson, N. J	" " A6
B. & O. R. R. Co	St. George, Staten Island	McMyler B2
"	"	Loco. Incline A4
"	"	" " A4
P. R. R	Port Greenville, N. J	" " A4
North River Co. (C. R. R. of N. J.)	Port Liberty, N. J	" " A6
Burns Bros., "	"	" " A4
Berwind-White Co. (P. R. R.)	Harsimus Cove, N. J	Grade A2
D., L. & W. R. R	Hoboken, N. J	Power Incline A8
"	"	McMyler B2
"	"	" B2
"	"	Endless Chain Conv'r. B5
D. & H	Weekawken, N. J	Power Incline A8
O. & W. R. R	Guttenberg, N. J	Loco. Incline A4
"	"	" " A4
Erie R. R	Edgewater, N. J	Power Incline A8
"	"	" " A8

* Maximum capacity of pier is 140 cars of

The principal data in connection with these piers are given in Tables 1, 2, 3, and 4, wherein the discharge is the maximum estimated capacity.

Output and Capacity.

The domestic and foreign shipments of coal from the various harbors during 1911 are given in Table 5.

Piers in New York Harbor.

Pier No.	Year built.	Length, in feet.	Height, in Feet.		Number of Tracks.				Grades. Percentage.				Discharge.				
			Shore.	Sea.	Appr.	Incl.	Deck.	Ret.	Appr.	Incl.	Deck.	Ret.	Sides.	Chutes.	Cars per 10 hours. Anthr.	Cars per 10 hours. Bitum.	Total.
1	..	1 800	17	35	..	2	4	..	..	1.0	1.0	..	1	16	200	....	200
2	'09	....	..	..	5	1	..	1	1.6	12.0	..	1.6	1	1	....	280	280
3	'11	....	..	..	3	1	..	1	1.6	12.0	..	1.6	1	1	100*	200*	300
4	..	900	25	25	6	..	4	2	0	0	0	0	2	18	....	120	120
1	..	850	30	24	4	..	4	1	0.6	..	0.6	1.0	2	20	160	....	160
2	..	750	26	20	4	..	4	1	0.6	..	0.6	1.0	2	20	140	....	140
1	'99	550	12	18	..	1	3	..	..	1.0	1.0	..	2	16	60	....	60
2	'93	800	35	16	..	2	4	2	..	3.0	1.5	3.0	2	24	....	160	160
3	'06	900	42	24	..	2	4	2	..	3.0	1.5	3.0	2	36	....	180	180
1	..	500	15	20	..	1	3	..	..	1.0	1.0	..	1	4	60	....	60
2	..	500	15	20	..	2	3	..	..	1.0	1.0	..	2	10	80	....	80
3	'06	900	26	40	..	4	4	..	..	1.5	1.5	..	2	24	190	10	200
..	..	1 500	33	18	..	2	4	2	..	3.0	1.5	3.0	2	21	250	....	250
1	'05	....	..	..	1	1	..	1	2.0	12.0	..	1.5	1	1	....	200	200
2	..	400	34	34	..	1	3	..	..	3.2	0	..	2	14	....	60	60
3	..	330	32	32	..	1	3	..	..	3.5	0	..	2	6	....	40	40
..	..	400	29	35	..	2	3	..	..	2.5	1.5	..	2	14	200	....	200
1	..	1 700	29	20	..	2	2	1	..	2.5	1.5	2.5	2	18	170	....	170
2	..	1 600	30	30	..	2	4	..	..	3.0	0	..	2	6	20	100	120
..	..	1 750	30	30	1	..	3	..	0	..	0	..	1	20	....	300	300
1	..	1 200	38	25	..	2	2	1	..	16.0	1.0	1.0	1	5	20	....	20
2	'03	1 280	5	5	..	1	..	1		See	details.		1	1	200	....	200
3	'03	1 280	5	5	..	1	..	1		"	"		1	1	200	....	200
4	'03	....	5	5	..	..	..	..		"	"		2	18	10	....	10
..	'91	1 080	36	26	..	2	4	1	..	16.0	1.3	1.5	2	32	160	....	160
1	..	600	29	35	..	2	4	..	..	1.5	1.0	..	2	12	120	....	120
2	..	600	29	35	..	2	4	..	..	1.5	1.0	..	2	11	120	....	120
1	'94	850	40	30	..	2	4	1	..	16.0	1.5	2.0	2	12	120	....	120
2	'94	850	40	30	..	2	4	1	..	16.0	1.5	2.0	2	12	120	....	120
															2 700	1 650	4 350

anthracite, or 300 cars of bituminous, in 10 hours.

TABLE 2.—DATA CONCERNING

Railway or operator.	Location.	Type.	Pier No.	Year built.	Length, in feet.	Height, in Feet. Shore.	Sea.
Pennsylvania R. R......	Greenwich, Phila......	Loco. Incline A4	1	'75	494	21	25
" "	" "	" " A4	2	'75	494	30	34
" "	" "	McMyler† B2	3	'13	800	14	14
" "	" "	Loco. Incl. A4	4	'75	641	28	42
" "	" "	Power Incl.........A8	6	'01	735	72	66
B. & O. R. R. Co.......	Jackson St., Phila.....	Loco. Incline.......A6	1	'93	600	37	33
Phila. & Reading Ry...	Port Richmond, Phila.	Grade App. & Ret. A2	4	'40	188	21	21
" " "	" " " .	" " " A2	8	'60	343	22	27
" " "	" " " .	" " " A2	10	'60	239	20	22
" " "	" " " .	Loco. Incl..........A4	11	'97	760	42	51
" " "	" " " .	Grade App. & Ret. A2	12	'65	201	21	22
" " "	" " " .	Loco. Incl..........A6	16	'92	714	38	30
" " "	" " " .	" " †........A4	18	'12	765	54	62

* Includes maximum capacities of piers under construction.

TABLE 3.—DATA CONCERNING

Railway or operator.	Location.	Type.	Pier No.	Year built.	Length, in feet.
B. & O. R. R. Co..................	Curtis Bay, Balto...........	Loco. Incline A6	..	'00	800
West. Maryland Ry...............	Port Covington, Balto.......	Power Incline A8	..	'05	735
Pennsylvania R. R.................	Clinton St. (Canton)........	Loco. Incline A6	..	'87	790
" "	Foot Potomac St. (Canton).	" " A4	3	'87	398
" "	" " " "	" " A4	4	'87	392
Georges Creek Coal Co., B. & O. R. R............................	Locust Point, Balto.........	Loco. Incline A4	..	'87	248
B. & O. R. R. Co..................	" " "	" " A4	..	'92	400
Merchants Coal Co., B & O. R. R.	" " "	" " A4	..	'87	150

Piers in Philadelphia Harbor.

Number of Tracks.				Grades, Percentage.				Discharge.				
										Cars per 10 hr.		
Appr.	Incl.	Deck.	Ret.	Appr.	Incl.	Deck.	Ret.	Sides.	Chutes.	Anthr.	Bitum.	Total.
1	3 & 2	3	..	....	+ 1.5	+ 0.78	......	1	10	130	....	130
1	3	4	..	....	+ 2.0	+ 0.87	......	2	19	...	300	300
4	1	1	1	— 1.8	+ 11.0	0.0	— 10 & 1	1	1	....	....	300
1	3	4	..	....	+ 2.25	+ 0.65	......	2	25	....	300	300
5	1	3 & 2	1	— 1.0	+ 17.5	— 1.0	— 2.8	2	40	....	....	300
1	1	2	1	0	+ 2.5	— 0.80	— 1.8	2	34	....	250	250
3	....	2	..	0	....	0	......	2	4	....	....	60
3	....	2	..	0	....	+ 1.36	......	2	11	....	100	100
3	....	3	..	0	....	+ 0.70	......	2	4	....	....	120
..	4	4	..	....	+ 1.25	+ 1.25	......	2	26	....	....	220
3	....	3	..	0	....	+ 0.58	......	2	6	60	....	60
4	2	2	2	0	+ 2.95	— 1.39	— 1.39	2	20	....	....	140
6	6	4	..	0	+ 2.08	+ 1.30	......	2	34	....	....	360
												*2 640

† Under construction.

Piers in Baltimore Harbor.

Height in Feet.		Number of Tracks.				Grades, Percentage.				Discharge.				
												Cars per 10 hr.		
Shore.	Sea.	Appr.	Incl.	Deck.	Ret.	Appr.	Incl.	Deck.	Ret.	Sides.	Chutes.	Anthr.	Bitum.	Total.
65	59	1	1 & 2	2	2 & 1	0	+ 2.0	— 1.0	— 2.0	2	48	..	300	300
67	60	1	1	2	1	— 2.0	+ 22.0	— 1.5	— 5.0 & — 3.0	2	40	..	250	250
42.2	38.6	1	2	2	1	+ 0.30	+ 2.0	— 0.50	— 0.47	2	24	..	120	120
19	21	..	3 & 1	3	..	..	+ 2.5	+ 0.50	....	2	10	80	....	80
27.5	29.5	1	2 & 5	5	..	+ 1.0	+ 2.5	+ 0.50	....	2	12	140	....	140
28	28	1	3	3	..	0	+ 5.0	0	....	2	10	..	60	60
35	35	1	1 & 3	3	..	0	+ 5.0	0	....	2	9	..	100	100
26	26	1	1 & 3	3	..	0	+ 5.0	0	....	2	4	40	....	40
												260	830	1 090

TABLE 4.—DATA CONCERNING

Railway or operator.	Location.	Type.	Pier No.	Year built.	Length, in feet.	Height, in Feet.	
						Shore.	Sea.
Norfolk & Western Ry.	Lamberts Pt., Va.....	Loco. Incline......A6	1	'85	869	48.2	43.5
" " "	" " "	" " A6	2	'92	797	47	41.5
" " "	" " "	Power Incline......A8	3	'01	867	77.1	70.4
" " "	" " †"	Combination.......C1	4	'13	1 200	91.5	91.5
Virginian Ry. Co......	Sewells Pt., Va........	Combination.......C2	1	'09	1 000	76.1	69.2
Chesa. & Ohio Ry.....	Newport News, Va....	Loco. Incline A6	2	'87	345	41.5	39.5
" " ".....	" " "	" " A6	3	'82	790	38.5	34
" " ".....	" " †"	Combination.......C1	9	'13	1 200	91.4	91.4
" " ".....	" " "	Loco. Incline A6	10	'00	450	51	48.5
" " ".....	" " "	" " A6	12	'07	850	59	55

* Includes capacities of piers under construction.

TABLE 5.—SHIPMENTS OF COAL, IN GROSS TONS.

Harbor.	Anthracite.	Bituminous.	Totals.
New York..........................	14 651 401	10 749 988	25 401 389
Philadelphia........................	2 197 750	4 856 626	7 054 376
Baltimore............................	257 025	4 002 809	4 259 834
Norfolk..............................	....	7 376 925	7 376 925
Totals..........................	17 106 176	26 986 348	44 092 524

Assuming that, on an average, a car contains 42 tons of coal, the tonnage in Table 5 indicates that about 1 050 000 cars were unloaded into boats of various kinds in 1911 from all the coaling ports.

The maximum capacities of the plants are given in Tables 1 to 4, and, as a general rule, are based on the largest number of cars handled in any one day, under favorable conditions of cargoes and deliveries. The average capacities are based on the deliveries obtained under ordinary conditions, where there is more or less delay due to the number and various sizes and kinds of cargoes, and approximate two-thirds of the maximum capacities.

PIERS IN NORFOLK HARBOR.

Number of Tracks.				Grades, Percentage.				Discharge.				Total.
										Cars per 10 hr.		
Appr.	Incl.	Deck.	Ret.	Appr.	Incl.	Deck.	Ret.	Sides.	Chutes.	Anthr.	Bitum.	
1	1	2	1	— 0.05	+ 2.3	— 0.66	— 2.5	2	22	..	150	150
1	1	2	1	— 0.05	+ 2.3	— 0.76	— 2.4	2	27	..	150	150
5	1	2	1	— 0.75 to — 1.33	+ 25.0	— 1.33 to — 0.67	— 2.83	2	60	..	400	400
					See sketch.			2	62	..	600	600
					See sketch.			2	62	..	300	300
1	1 & 2	2	1	0	+ 1.0 & 2.0	— 0.63	— 3.0 & — 2.5	2	9	..	150	150
1	1	2	1	0	+ 1.0	— 0.59	— 0.59	2	28	..	250	250
					See sketch.			2	66	..	600	600
1	1 & 2	2	1	0	+ 2.0	— 0.65	— 2.2	2	20	..	200	200
1	1 & 2	2	1	0	+ 2.0	— 0.65	— 2.2 & — 1.0	2	39	..	380	380
											*3 180	3 180

† Under construction.

During any of the past 8 years, the ratio of the actual maximum output to the estimated maximum capacities, as indicated in Tables 1 to 4, is about:

51% in New York Harbor;
29% " Philadelphia Harbor;
31% " Baltimore Harbor;
30% " Norfolk Harbor.

If all the ports had worked to their average estimated capacities, they could have discharged their output of 1911 in the following times:

New York Harbor.............. 222 days.
Philadelphia Harbor .... 185 "
Baltimore Harbor .... 195 "
Norfolk Harbor .... 141 "

It will be noted that in New York Harbor the maximum output for any one of the past 8 years developed 51% of the maximum estimated capacity, and Philadelphia, Baltimore, and Norfolk only delivered about 30 per cent. This apparently better showing in New York Harbor can be explained by the fact that in that harbor there is an

almost continuous run of cargoes varying from 50 to 3 500 tons for local consumption, and in other harbors the local consumption from the piers is not nearly as great; also, the cargoes are generally larger and of less frequency.

On the basis of the estimated maximum capacities of the various piers, the percentages of coal furnished by each of the roads serving would be about as given in Table 6.

TABLE 6.—PERCENTAGES OF COAL FURNISHED BY RAILROADS.

Railroad.	Harbors.				Total for all harbors.
	New York.	Philadelphia.	Baltimore.	Norfolk.	
Pennsylvania	32.0	53.2	31.0	....	30.0
Central of New Jersey	20.0	....	....	....	9.0
Delaware, Lackawanna and Western	10.0	....	....	....	4.5
Philadelphia and Reading	9.0	34.5	....	....	12.0
Baltimore and Ohio	7.0	12.3	46.0	....	11.0
Lehigh Valley	7.0	....	....	....	3.0
Erie Railroad	5.5	....	....	....	2.5
Ontario and Western	5.5	....	....	....	2.5
Delaware and Hudson	4.0	....	....	....	2.0
Western Maryland	....	....	23.0	....	3.0
Chesapeake and Ohio	....	....	....	49.5	10.0
Norfolk and Western	....	....	....	35.5	7.5
Virginian	....	....	....	15.0	3.0
Totals	100.0	100.0	100.0	100.0	100.0

From the fact that the actual annual output of these ports represents only from 141 to 222 working days under average capacity for the four harbors, it may be reasonably inferred that the existing ports are capable of supplying greater demands for coal than now exist; but, of course, it must be remembered that a pier which supplies a succession of small cargoes, and especially to boats not under their own power control, will not be able to work to the same capacity as in cases where there will be the same continuous run of large cargoes regularly, and, though some of the ports may be hard pressed at times to make deliveries satisfactory to urgent demands, there are other ports which are more or less idle a great part of the time, and all the piers are idle some of the time, due to lack of vessels. The necessity of being in a position to furnish large cargoes in a short time requires, in a number of the ports, the construction of piers of greater capacity than they will be required to develop, except at intervals.

The capacity of many of the piers is also restricted by lack of yard facilities, or by lack of proper adaptation for the kind of cargoes handled, the height, in a number of cases, being insufficient to permit of a free discharge of coal from the pockets to the vessels. The piers having the largest estimated maximum capacities per day of 10 hours in the various harbors are given in Table 7.

TABLE 7.—PIERS IN EACH HARBOR HAVING THE LARGEST ESTIMATED MAXIMUM CAPACITY.

Harbor.	Railroad.	Piers.	Location.	Type.	Number of cars.
New York...	P. R. R........	No. 3.	South Amboy..	McMyler dumper, Type B2....	300
	P. R. R........	....	Harsimus Cove	Grade approach and return, Type A2.....................	300
Philadelphia.	P. R. R........	No. 6.	Greenwich.....	Power incline, Type A8........	350
	P. R. R........	Nos. 2 and 4.	"	Locomotive incline, Type A4.	300
Baltimore....	B. & O..........	....	Curtis Bay....	Locomotive incline, Type A6.	300
Norfolk......	N. & W........	No. 3.	Lamberts Point........	Power incline, Type A8........	400
	C. & O........	No. 12.	Newport News	Locomotive incline, Type A6.	380
	Virginian R.R.	....	Sewells Point..	Combination, Type C2.......	300
	New combination plants, Type C1, under construction, one for N. & W. at Lamberts Point and one for C. & O. at Newport News, will have a maximum capacity of..............................				600

CARGOES.

In New York Harbor coal is delivered mostly to lighters and barges up to 3 500 tons capacity, there being but few sea-going vessels which are coaled directly from the piers, either in bunkers or in cargoes. These are usually loaded from lighters. Some piers are prepared to furnish coal in from 5- to 10-ton lots, but most of the cargoes delivered are not less than 50 tons.

In Philadelphia Harbor coal is delivered to local tugs, barges, schooners, scows, tramps, and colliers, the greater portion being in barges for domestic use, cargoes running up to 3 500 tons, and to a number of tramps of from 5 000 to 7 000 tons, with an occasional collier of 12 500 tons.

In Baltimore Harbor coal is delivered to small bay craft up to 50 tons, coastwise sailing vessels with cargoes of from 1 500 to 6 000 tons, barges up to 7 500 tons, tramps from 5 000 to 7 000 tons, and colliers of 12 500 tons. A large part of this coal goes to New England and to foreign countries.

In Norfolk Harbor cargoes are delivered to boats of about the same class as in Baltimore Harbor, but some of the Norfolk piers are better adapted for furnishing coal to the largest Government colliers.

The two largest Government colliers, the *Cyclops* and *Neptune*, have a length of 542 ft., beam 65 ft., hatches 32 ft. athwartships, 13 ft. fore and aft; the top of the forward cargo hatch when the boat is in ballast trim is about 30 ft. above the water level, and the aft cargo hatch 25 ft., the bunker hatches being about 38½ ft. When out of ballast trim, a condition which may occur rarely, the aft bunker hatches may be about 43 ft. above the water line. Their main draft when loaded is 27 ft. 7 in. On account of the steel cranes and derricks on the decks of these boats, it is somewhat difficult to coal them.

The largest coastwise steamer of the New England Coal and Coke Company is the *Malden*, which has a length of 406 ft. over all, beam 54 ft. 6 in., ten cargo hatches 30 ft. athwartships and 15 ft. fore and aft, one bunker hatch 24 ft. athwartships, 7 ft. fore and aft. The distance from the top of the cargo hatches to the water, when the boat is in ballast trim, varies from 26 to 32 ft., and the bunker hatch is 32 ft. It is probable that in the future this company will build colliers up to 550 ft. in length, with from 65 to 70 ft. beam.

Channels and Tidal Variations.

The present depths of the channels leading to the various ports in the four harbors are given in Table 8.

Classification of Coal Plants.

The coal piers constructed for the purpose of supplying coal to vessels in the harbors of the Atlantic Seaboard may be divided into the three general classes:

(A) Gravity Plants,
(B) Mechanical Plants,
(C) Combination Plants.

A.—Gravity Plants.

This name is generally given to coal trestles which are equipped with pockets or bins for receiving the coal from the usual cars, and with chutes for discharging it into vessels moored at the piers. Although a number of these plants have such grades as will permit the loaded cars to drift over the deck tracks and the empties to return to the

yards by gravity, there are also a number where the grades are so light that power of some kind is required for the movement of the loads over the deck and of the empties to the yards; but, no matter what the grades or how the cars are moved on the deck and on the return tracks, the pier is classed as a gravity plant if the coal is discharged directly into the pockets or chutes from the regular coal cars on the tracks on top of the pier.

The general class of gravity plants embraces nine types, as shown by Figs. 1 and 2.

TABLE 8.—DEPTHS OF CHANNELS, AND TIDAL VARIATIONS.

Harbor.	Port.	Channels, etc.	Depth, in feet.	Tidal Variations, in Feet.	
				Mean.	Maximum.
New York...	South Amboy.....	Raritan Bay..........	21	4.5	6.3
	Perth Amboy......	" "	21		
	Port Reading....	Arthur Kill..........	21		
		Staten Island Sound and Kill van Kull..........	16		
	Elizabeth Port..	Kill van Kull..........	16		
		Arthur Kill and Staten Island Sound..........	21		
	Port Johnson......	Kill van Kull..........	26		
	St. George.........	Upper and Lower Bays..........	40		
	Greenville.......	Upper and Lower Bays..........	40		
		Local to pier..........	18		
	Port Liberty......	Upper and Lower Bays and Hudson River..........	40		
	Harsimus Cove....	Upper and Lower Bays and Hudson River..........	40		
	Hoboken...........	Upper and Lower Bays and Hudson River..........	40		
	Weehawken........	Upper and Lower Bays and Hudson River..........	40		
	Guttenberg	Upper and Lower Bays and Hudson River..........	40		
	Edgewater.........	Upper and Lower Bays and Hudson River..........	40		
Philadelphia.	Greenwich.........	Delaware River 27 ft., being dredged to :..........	35	5.3	5.8
	Jackson St........	Delaware River 27 ft., being dredged to :..........	35		
	Port Richmond....	Delaware River 27 ft., being dredged to :..........	35		
Baltimore....	Curtis Bay.........	Local channel 31 ft., Harbor channel..........	35	1.2	6.0
	Port Covington....	Local channel 25½ ft., Harbor channel..........	35		
	Canton..........	Clinton St., 30 ft., Harbor channel.	35		
		Piers 3 and 4 22 ft., Harbor channel..........	35		
	Locust Point......	Local channel 27 ft., Harbor channel..........	35		
Norfolk......	Lamberts Point...	Hampton Roads and Elizabeth River..........	35	2.7	3.1
	Sewells Point......	Hampton Roads..........	35		
	Newport News....	Hampton Roads and James River.	35		

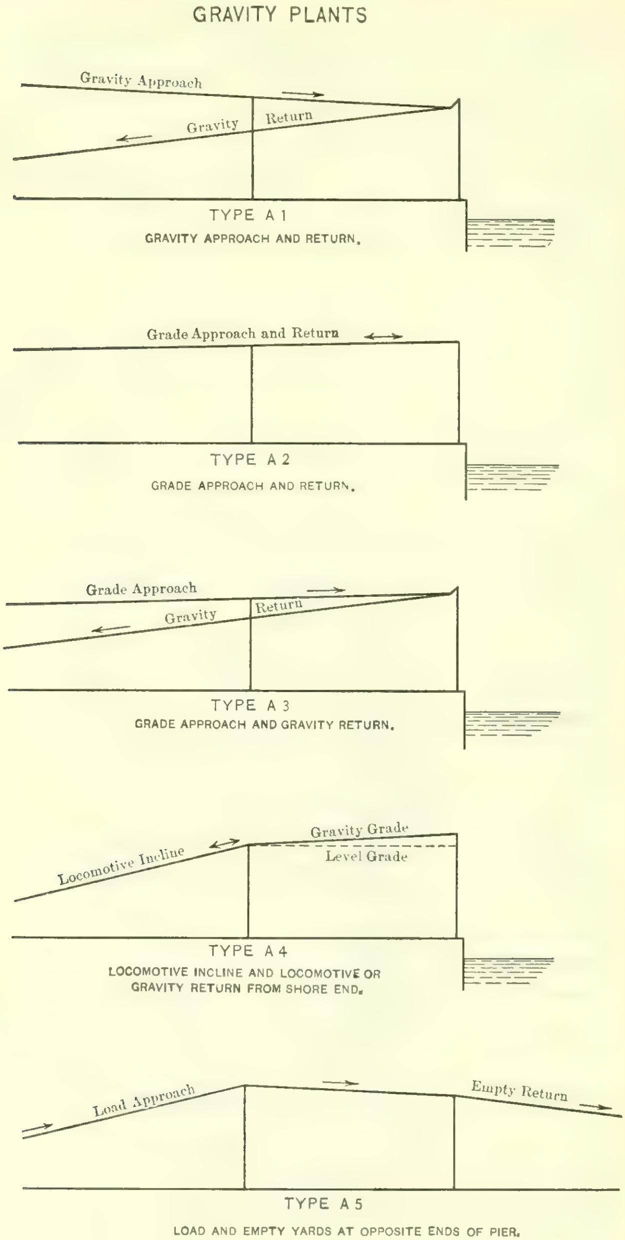

GRAVITY PLANTS
Gravity Approach
Gravity
Return
TYPE A 1
GRAVITY APPROACH AND RETURN.
Grade Approach and Return
TYPE A 2
GRADE APPROACH AND RETURN.
Grade Approach
Gravity
Return
TYPE A 3
GRADE APPROACH AND GRAVITY RETURN.
Locomotive Incline
Gravity Grade
Level Grade
TYPE A 4
LOCOMOTIVE INCLINE AND LOCOMOTIVE OR
GRAVITY RETURN FROM SHORE END.
Load Approach
Empty Return
TYPE A 5
LOAD AND EMPTY YARDS AT OPPOSITE ENDS OF PIER.

FIG. 1.

GRAVITY PLANTS

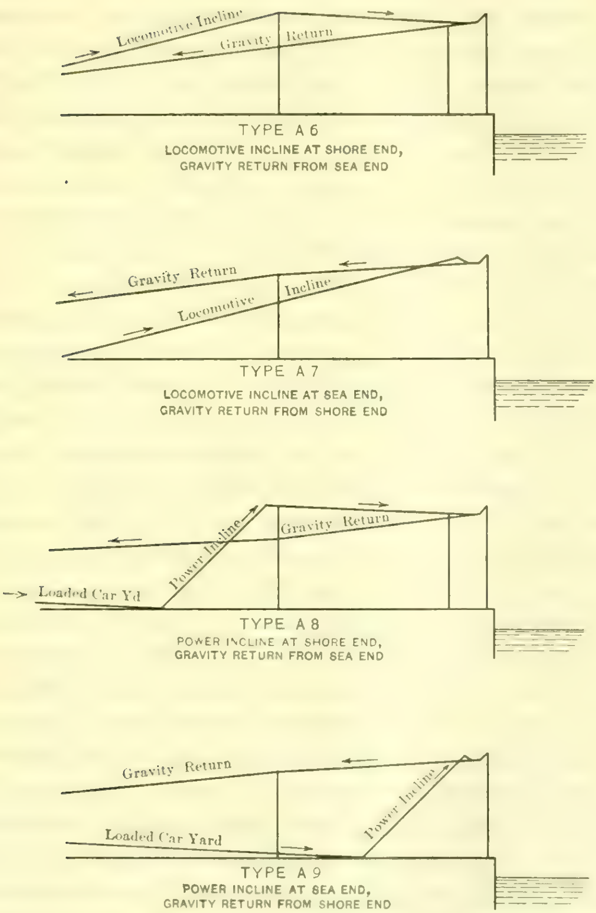


Fig. 2.

Type A1.—Gravity Approach and Return.—The loads are delivered to the pier deck, spotted over the pockets, and the empties returned to the yards, all by gravity. This is the ideal type of gravity plant; but locations where the land back of the dock is at a sufficient elevation for a gravity lead to the pier deck, and where the empty yard can be constructed at an elevation lower than the deck of the pier, are not usual in harbors. As a matter of fact, the writer has been unable to locate any pier of this type on the Atlantic Seaboard within the limits of the United States. In the Perth Amboy Port of New York Harbor, Piers Nos. 1 and 2, operated by the Lehigh Valley Railroad Company, have a descending grade of 0.6% on the trestle approach and a 1% grade for the return of empties, but as the 0.6% approach grade will not permit cars to move by gravity except under very favorable weather conditions, and as locomotives are therefore used, these piers cannot be considered as meeting the conditions of this ideal type.

Type A2.—Grade Approach and Return.—The pier deck beyond the bulkhead of the slips is at approximately the same elevation as the tracks on the approach trestlework and in the yards, thereby requiring locomotives for delivering the loads on the deck and for removing the empties. The grades may be level, or slightly ascending, or descending. On account of engine service for both loads and empties, on the deck as well as in the yards, the operating cost of this type may be high, the discharge and return of the cars slow, and the capacity of the pier somewhat restricted thereby, especially when there are only one or two tracks on the pier; but as more cars can be handled by a locomotive on easy grades than on steep inclines, the cost of operation of this type may be low, or lower than any of the types where empties are returned by gravity, when the character of the vessels, loads, and their cargoes will not permit of continuous operation. It will depend largely on the number and types of vessels and cargoes. There are two piers of this type in service in New York Harbor and four in Philadelphia.

Type A3.—Grade Approach and Gravity Return.—The pier deck is at approximately the same elevation or grade as the tracks on the approach trestlework, but at a higher elevation than in the empty yard. Loads are delivered on the pier by locomotives and the empties are returned by gravity. This type, on account of the easy delivery grade, where a considerable number of cars can be handled by one locomotive, and the return of empties by gravity, should be economical in operation

where conditions are such as to enable its construction without sacrifice of yard facilities and operations, and without an excessive expenditure for the construction and maintenance of long and high trestle approaches. There are only two piers of this type, both in New York Harbor.

Type A4.—Locomotive Incline at the Shore End and Locomotive or Gravity Return from the Shore End.—The pier deck may be level or have a slight grade. The loads are pushed up the incline by a locomotive and are then handled and the empties removed by the locomotive, or the empties are spotted by gravity or by using pinch-bars and then returned by gravity down the delivery incline, depending on the grades. This is a simple type of so-called gravity pier, and is used where the width of right of way is contracted and local conditions are such as to necessitate the construction of a joint yard for loads and empties within a restricted space. The empties may be returned over the delivery tracks, for piers where the output is small, or over independent tracks, where the output is large and the right of way will permit the additional width necessary for such tracks. There are eleven piers of this type in New York Harbor, five in Philadelphia, and five in Baltimore, making a total of twenty-one now in operation.

Type A5.—Load and Empty Yards at Opposite Ends of Pier.—The loads are pushed from the yard up the incline at one end of the pier, and the empties are returned to the yard at the other end, the entire movement of cars being in one direction. This type may be used along the banks of rivers or canals, where the yards and tracks have to be parallel to the stream, and is used for locomotive coaling stations, but, so far as the writer has been able to discover, there are no piers of this type on the Atlantic Seaboard.

Type A6.—Locomotive Incline at Shore End, Gravity Return from Sea End.—Loads are pushed up the incline to the deck by a locomotive, then drift by gravity over the pockets, and, when unloaded, drop by gravity to a switchback or turn-table, where the movement is reversed to the empty yard. The empty return tracks, being independent of the approach tracks, may be graded so as to reach an empty yard adjoining the load yard or at almost any convenient location, without impeding operations. All things considered, this type is perhaps the most practical and economical of the gravity plants, both as to cost and operation, and is sufficiently flexible to meet a diversity of local

conditions. There are four piers of this type in New York Harbor, two in Philadelphia, two in Baltimore, and six in Norfolk, making a total of fourteen now in operation. The Baltimore and Ohio pier at Curtis Bay, Baltimore Harbor, is a well-known example.

Type A7.—Locomotive Incline at Sea End, Gravity Return from Shore End.—This is simply a modification of Type A6. The lead for the yard tracks is nearer the water and the empty yard is farther back than in Type A6. The deck of the pier has an ascending grade toward the sea end, thereby making the highest part of the deck at the place where it is of most service. There are no piers of this type in operation, so far as can be learned by the writer, but the advantages of the type in certain locations make it worthy of consideration.

Type A8.—Power Incline at Shore End, Gravity Return from Sea End.—The pier has a down grade toward the sea. Cars are pulled up the incline by a cable and stationary engine, or are pushed up by a small car or barney attached to the end of a cable. Otherwise the operation is the same as in the locomotive incline, Type A6. The power inclines, with their steep grades, are adaptable to locations where the space at the approach to the pier is not sufficient for a locomotive incline. The delivery track from the loaded yard is usually graded downward so as to feed the cars to the foot of the incline by gravity. There are four piers of this type in New York Harbor, one in Philadelphia, one in Baltimore, and one in Norfolk, making a total of seven, exclusive of a similar plant in combination with a mechanical plant, which is embraced under another classification.

Type A9.—Power Incline at Sea End, Gravity Return from Shore End.—The pier has an up grade toward the sea, and is simply a modification of Type A8. The highest part of the deck is at the sea end, where the highest chutes properly belong. This type, when vessels are loaded from only one side of the pier, is well adapted to localities where the load yard is close to the pier. When piers deliver coal to vessels on both sides, the delivery track can be placed in the middle and the deck tracks can be carried across the entire width of the pier, except for the space required for the incline through the deck, thereby requiring less width of pier at the shore end than for Type A8. There are no piers of this type in operation on the Atlantic Seaboard, but it is worthy of consideration in favorable locations.

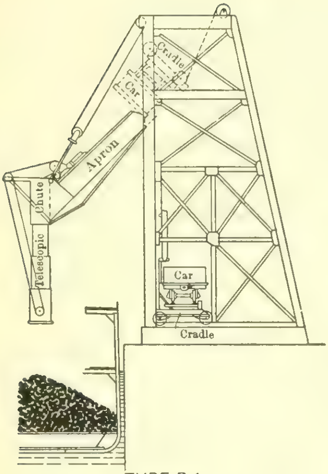
B.—Mechanical Plants.

Coaling plants which are equipped with car-dumping machinery, elevators, conveyors, etc., for delivering coal to vessels without the use of high and long trestles, are classed as mechanical. The car-dumping machines pick up the loaded cars and dump their contents on an apron, from which it flows into vertical chutes which are adjustable and kept full of coal so as to reduce the fall and breakage. These machines vary somewhat in design, and are manufactured by the McMyler Manufacturing Company, the Wellman-Seaver-Morgan Company, the Brown Hoisting and Conveying Machine Company, all of Cleveland, Ohio. A description of the several types of mechanical plants (Figs. 3 and 4) follows:

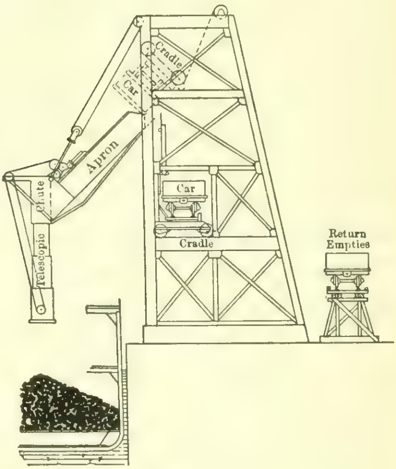
B1.—Car-Dumping Machine at Grade.—The loaded car is delivered near the cradle of the machine, which is at grade or only a slight elevation above it, and is placed or hauled on the cradle. It is then lifted vertically and dumped into chutes by turning it over sideways. The car is then lowered, pushed off the cradle by the next loaded car entering, and hauled away. The range of delivery to vessels is confined within the sweep of the chutes, and this necessitates moving the vessels while being loaded. This type is adapted to locations where space is restricted to such an extent that the gravity movement of empty cars is impracticable, but there is no plant of this particular type in operation on the Atlantic Seaboard.

B2.—Car-Dumping Machine with Power Incline.—The loaded car is delivered by gravity or locomotive to a barney or cable connection which moves up a steep inclined plane to the cradle of the machine. It is then dumped into chutes by turning it over sideways, and the empty car is returned to the yard by gravity. This type requires more space than B1, and, as the cars are delivered at an elevation, the vertical lift of the machine need not be as great. When space is available, this plant is more economical of operation than Type B1. There are five plants in New York Harbor and one in Philadelphia, a total of six on the Atlantic Seaboard, exclusive of those used in combination with gravity piers and included in Class C.

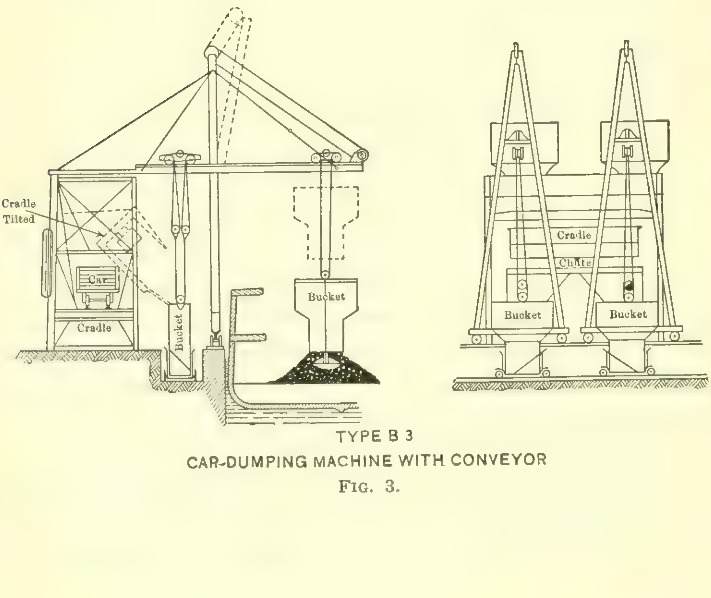
B3.—Car-Dumping Machine with Conveyors.—The machine turns the car over sideways and dumps the coal into conveyor buckets which carry it from the machine and lower it to the bottom of the hatch before dumping. The cars may be handled by locomotives or by



TYPE B 1
CAR-DUMPING MACHINE AT GRADE



TYPE B 2
CAR-DUMPING MACHINE WITH BARNEY

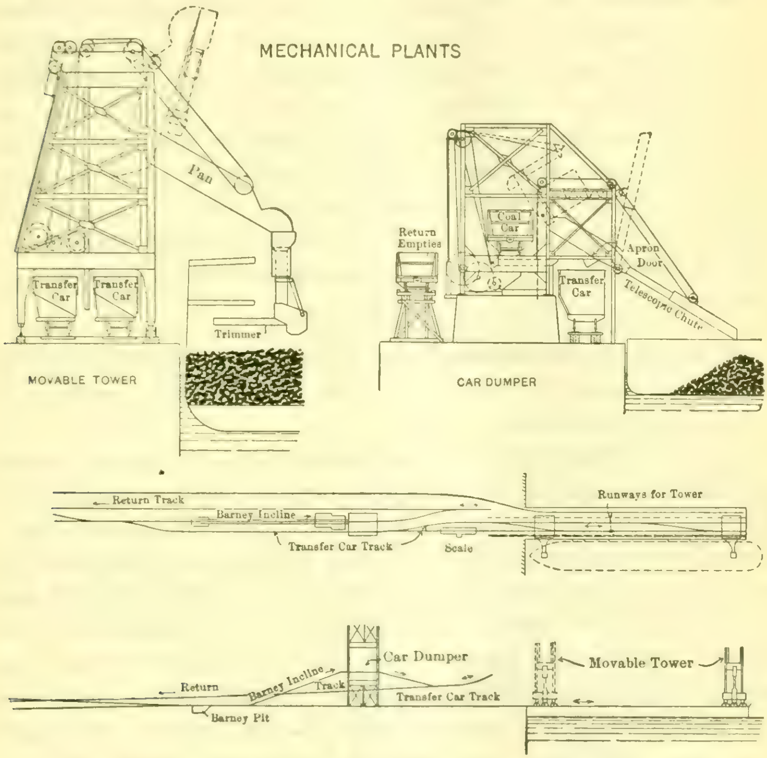


TYPE B 3
CAR-DUMPING MACHINE WITH CONVEYOR

FIG. 3.

barneys and gravity. It is claimed that this will reduce the breakage of coal to a minimum. There are no plants of this type on the Atlantic Seaboard, but one is in operation at Buffalo, N. Y.

B4.—Car-Dumping Machine with Movable Tower.—The loaded car is delivered by a locomotive or by gravity to a barney, which moves it up an inclined plane to the cradle of the machine. It is then dumped



TYPE B4-CAR-DUMPING MACHINE WITH MOVABLE TOWER

FIG. 4.

into a self-propelling transfer car having a sloping bottom and discharge, which moves on to a movable tower. The tower moves on tracks running along the pier, and elevates the body of the transfer car vertically to the proper height; then the coal flows from the side of the car into chutes. The body of the transfer car is then lowered to its tracks. The empty transfer cars return for another load and the empty coal cars are returned to the yard by gravity. This type is very

elastic, and will deliver coal at any part of the pier without moving the vessels. When provided with a mechanical trimmer, as indicated on the sketch (Fig. 4), the cost of trimming coal may be reduced considerably. There are as yet no plants of this type in operation on the Atlantic Seaboard, but a number of designs have been under consideration.

B5.—Endless Chain Conveyors.—The coal is dumped into a hopper and then elevated by an endless chain conveyor to such a height that the coal will run into bins and be delivered to the hatches through chutes. This type is indicated in particular cases where the local and congested conditions will not permit of sufficient space to turn the cars so that they may be run on the piers, as in cases where the supply track runs at right angles to the pier and close to the shore end. There is one plant of this type in New York Harbor at the end of a pier in the Hoboken Port of the Delaware, Lackawanna and Western Railroad.

C.—Combination Plants.

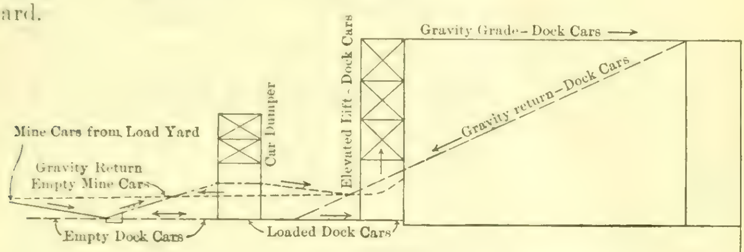
It is quite possible and practicable to combine car-dumping machines with gravity piers in a variety of ways. Two of these combinations are described, as follows:

Type C1.—This type is a combination of a car-dumping machine (power incline and gravity return of empty mine cars) with an elevator lift to a gravity pier deck at the shore end for special dock cars, and a gravity return of empty dock cars from the sea end. The mine cars are dumped by the machine into special dock cars which move by their own power, or by gravity, to the platform of the elevator, are then raised to the deck of the pier, over which they move by their own power, or gravity, and discharge coal into the pier pockets and chutes, and then return under brake control to the car dumper. The empty mine cars which have been unloaded by the car dumper return by gravity to the empty yards. Two plants of this type are under construction in Norfolk Harbor, one at Lamberts Point and the other at Newport News. See Fig. 5.

Type C2.—This type is a combination of car-dumping machine (power incline and gravity return of empty mine cars) with Type A8, a gravity plant power incline for special dock cars at the shore end and a gravity return of these cars at the sea end. In this type the dumping machine empties the mine cars into a special dock car, these special dock cars are pushed to the top of the pier over the

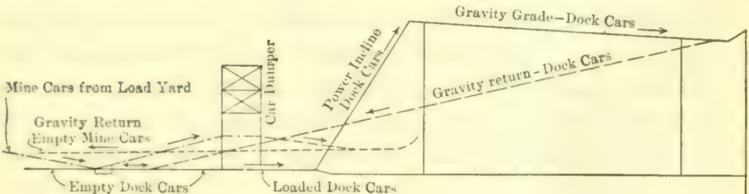
barney incline, and are then dropped by gravity, or under their own control, to the pockets where the coal is delivered; they are then returned to the car dumper under brake control over the gravity return. The empty mine cars drift by gravity over the switchback to the empty yards. There is one pier of this type in Norfolk Harbor at Sewells Point. See Fig. 5.

Table 9 shows the number of each class and type of plant now in operation or under construction in the harbors of the Atlantic Seaboard.



TYPE C 1

CAR-DUMPING MACHINE (POWER INCLINE AND GRAVITY RETURN OF EMPTY MINE CARS) WITH ELEVATOR LIFT TO PIER DECK AT SHORE END FOR SPECIAL DOCK CARS, AND GRAVITY RETURN OF EMPTY DOCK CARS FROM SEA END.



TYPE C 2

CAR-DUMPING MACHINE (POWER INCLINE AND GRAVITY RETURN OF EMPTY MINE CARS) WITH TYPE A 8, GRAVITY PLANT, POWER INCLINE FOR SPECIAL DOCK CARS AT SHORE END AND GRAVITY RETURN OF SPECIAL DOCK CARS FROM SEA END.

FIG. 5.

DIMENSIONS.

The longest coal pier, measured from the bulkhead to the end of the slip, is Pier No. 1, Pennsylvania Railroad Company, at South Amboy, N. J., which has a length of 1 800 ft. The length of the Curtis Bay pier of the Baltimore and Ohio Railroad is 800 ft., of the Norfolk and Western pier at Lamberts Point, 867 ft., of the Virginian Railway pier at Sewells Point, 1 000 ft., of Pier No. 12 of the Chesapeake and Ohio Railway at Newport News, 850 ft., and of Pier No. 6 of the Pennsylvania Railroad at Greenwich, Pa., 735 ft. These represent

the lengths of the slips. The two piers at Norfolk now under construction, one for the Norfolk and Western Railroad and one for the Chesapeake and Ohio Railroad, will have slips 1 200 ft. long.

TABLE 9.—NUMBER OF EACH CLASS AND TYPE OF PLANT IN OPERATION OR UNDER CONSTRUCTION IN THE HARBORS OF THE ATLANTIC SEABOARD.

Harbor.	GRAVITY PLANTS. CLASS A.										MECHANICAL PLANTS. CLASS B.						COMBINATION PLANTS. CLASS C.		
	A1.	A2.	A3.	A4.	A5.	A6.	A7.	A8.	A9.	Total.	B1.	B2.	B3.	B4.	B5.	Total.	C1.	C2.	Total.
New York	..	2	2	11	..	4	..	4	..	23	..	5	..	..	1	6	....	..	....
Philadelphia	..	4	..	5*	..	2	..	1	..	12	..	1†	..	..	..	1	....	..	....
Baltimore	..	..	..	5	..	2	..	1	..	8	..	....	..	..	..	....	....	..	....
Norfolk	..	..	..	....	..	6	..	1	..	7	..	....	..	..	..	....	2†	1	3
Totals	0	6	2	21	0	14	0	7	0	50	0	6	0	0	1	7	2	1	3

* One plant under construction and four in service.
† Under construction.

The highest pier thus far built is the Norfolk and Western Pier No. 3, at Lamberts Point, which has a height of 70.4 ft. above the water near the sea end. The Curtis Bay pier of the Baltimore and Ohio Railroad has a height of 59 ft. near the sea end, the Virginian Railroad pier at Sewells Point has a height of 69.2 ft., and the two piers under construction at Lamberts Point and Newport News will have a height of about 91½ ft.

The heights and lengths of all piers on the Atlantic Seaboard are noted in Tables 1 to 4. The highest piers, namely, those under construction at Newport News and Lamberts Point, will have a maximum height of 47 ft. from the discharging end of the chute to the water, and a minimum of 5 ft.

The dimensions of the largest U. S. naval colliers and coastwise steamers carrying cargo coal are given under the heading, "Cargoes." In order to coal freely into coastwise boats, the maximum height of hatches being 32 ft., the height of piers should not be less than 65 ft. above mean tide, when the pier is not provided with storage bins, and, if bins are provided for storing one car of coal each, the height should be at least 70 ft. above mean tide. For coaling the largest Government

colliers freely, the height should be at least 8 ft. greater than the foregoing, and to meet the possible conditions when the boat is out of ballast, the height should be at least 13 ft. greater.

Piers with heights 5 ft. less than those given will coal to the same class of boats, but not freely, because the chutes will be inclined at too flat an angle for the gravity flow of coal. A pier only 50 ft. high above mean tide can be made to deliver coal to some of the coastwise steamers with capacities up to 7 000 tons, but at extra expense for handling and trimming. As a general proposition, for efficient service to boats of all classes, the height of a pier should be from 33 to 43 ft. greater than the height of the highest hatches of vessels coaling at the ports, depending on the type of chute used and the storage capacity of the bins.

Tracks and Grades.

The tracks leading to piers and yards are usually arranged so as to require the least number of shifting operations. In some yards a large number of short tracks are required to sort cars with different kinds of coal, and when this is the case, the load yard, when practicable, consists of a number of short tracks, or a gridiron arrangement with a ladder at each end. For the empty car yard, sorting is generally not necessary, and a few long tracks are used. The approach tracks to locomotive inclines usually have as great a length as the situation will permit, in order to enable locomotives to have a good run for overcoming the grade of the incline. The approach tracks leading to barney inclines have a down grade where the conditions will permit, in order that the cars may drift by gravity to the barney. Tracks on the piers are arranged in a number of ways, depending on the local conditions, the type of pier, and whether coaling is done from one or both sides.

The grades on locomotive inclines vary from 1 to 5 per cent. There are only three piers having grades of 5%, six with grades from 3 to 3½%, and twenty-six with grades less than 3 per cent. The conditions which affect the choice of the grade are: longitudinal space, capacity of the locomotive to be used, the required discharging capacity of the pier, and economy of operation and cost. A steep locomotive incline will cost less to construct, but usually more to maintain and operate, than an easy or moderate grade, and, as the delivery of the coal to

the pier deck should keep pace with the discharge into vessels, for economical operation, the grade should not be such as to retard delivery. The selection of the grade on locomotive inclines is an important matter, and should be determined, not so much from what is in use on other piers as by a study of the local conditions and requirements for each case, and when conditions permit, it should not exceed 3 per cent.

The grades on barney or cable inclines to gravity class piers vary from 16 to 25%, and on mechanical classes from 11 to 12 per cent. It will require less power and less expensive machinery to pull a car up a 12% grade than up a 25% grade, and though the steeper inclines are usually resorted to on account of limited longitudinal space, it is economy to use the easiest grade permitted by the local conditions—economy even in first cost—as the additional cost of the longer low-grade trestle is often offset by the cost of less expensive machinery, and there is less danger of accident. In mechanical classes of plants, as the inclines are required for relatively small height, it is not necessary to give them a very steep grade. A 16 to 18% grade on a gravity plant, and 10 to 12% on a mechanical plant, appear to be reasonable.

The grades on pier decks vary from 0.5 to 1.5 per cent. When the grade is less than 1%, a short, sharp grade is sometimes introduced to give an impetus to the cars at the head of the pier and at the switch-back. The object of a grade on the pier deck is to enable cars to move slowly by gravity. In the summer cars in good condition will run freely on an 0.8% grade without resort to pinch-bars. As coal is delivered to vessels during cold as well as warm weather, and in northern as well as southern climates, the selection of a grade for any pier is more or less a matter of compromise; grades from 1 to 1.3% give good results in New York, but grades from 0.67 to 0.76% appear to give equally good results in the South when headed by a sharp starting grade.

Grades for the return tracks vary from 0.6 to 5% for hand-brake control, but it is considered good practice to keep them less than 2% when practicable, and to ease them off as their lower ends approach the empty yard. The percentage of grade of the return track is governed to a considerable extent by the location of the empty yard.

All changes in grade are eased by vertical curves extending for

a distance of from 35 to 50 ft., and even for a longer distance, where circumstances warrant, depending on the degree of change and the length of grades. The number of tracks on approaches, including deck and empty return, with their grades, are given in Tables 1 to 4.

Switchbacks and Pivot Tables.

Switchbacks are intended to work automatically, and have grades and lengths proportioned so as to keep the empty cars moving by gravity. They are generally constructed with adjustable blocking, in order that the grades may be quickly adjusted during the different seasons of the year, as those having grades satisfactory for handling cars by gravity in hot weather will not operate well in cold weather and *vice versa*. The grades, etc., of a typical switchback are indicated on the sketch, Fig. 6.

In some cases, where longitudinal space will not permit the construction of a switchback, counterbalanced transfer or pivot tables are used. The normal position of the table is in line with the delivery track. Cars are run on the table by gravity, and the table moves by gravity to a connection in line and grade with the return track, the empty car then leaves the table by gravity, and the table is returned to its normal position by the counterweight. Pivot tables of this character are in use at Lamberts Point, Piers Nos. 1 and 2, in Norfolk, and at Port Covington and Clinton Street in Baltimore. One man is required at each table to control the brake levers governing the movement of the table. The arrangement of a typical table is shown on the sketch, Fig. 6.

Wherever there is sufficient space for the construction of a properly designed switchback, it is preferable to a pivot table, as it has less mechanism to get out of order and is equally effective.

Equipment.

The equipment in connection with the gravity type of pier as herein discussed embraces bins, pockets, chutes, and power-incline mechanism, and, for all classes of piers, scales and thawing plants.

Bins and Pockets.—For the purposes of this paper, the following classification of bins and pockets on coal piers has been made:

Bins.—Hoppers or receptacles constructed for the purpose of storing coal temporarily or permanently;

Pockets.—Hoppers constructed to receive the coal from the cars and to deliver directly into the chutes without storage.

There are various forms of construction of bins and pockets; a general description of each follows.

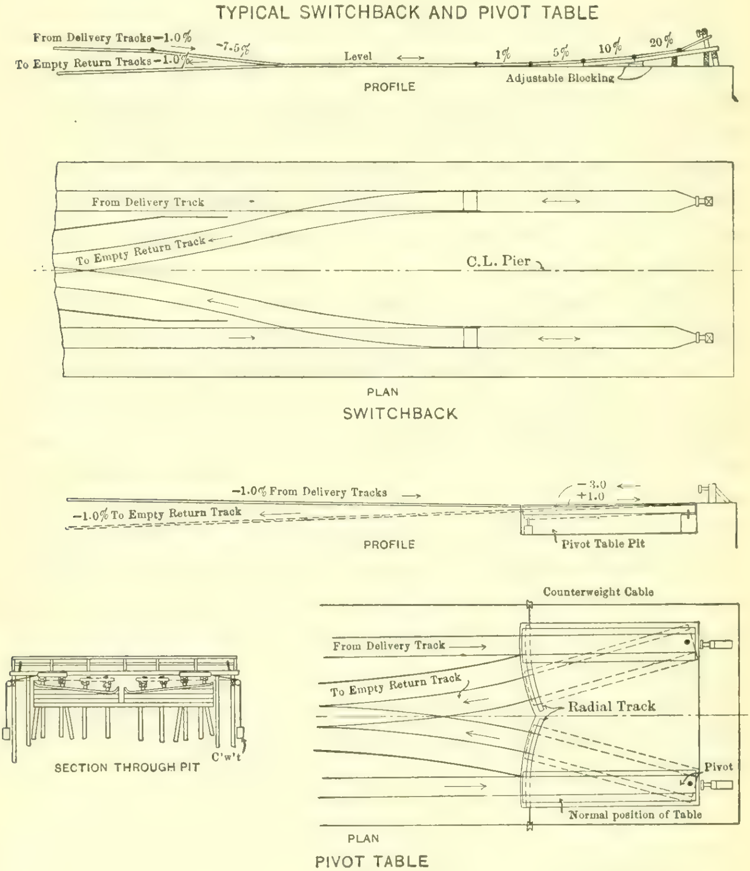


FIG. 6.

Bins in most cases consist of partitions framed to timber bents of the approach trestle; they have wooden floors, and the coal is dropped from the car bottoms through openings in the deck. In some instances these bins are constructed with enclosed sides and with a hopper bottom, so that the coal may be reloaded into cars or loaded into wagons

or boats through chutes. When bins have sides and hopper bottoms they are usually lined with sheet metal.

Pockets are ordinarily used to receive the coal as it drops from the hopper bottom of the car and convey it to the chutes. Pockets are located under the delivery tracks on the pier, and have their bottom outlet at the side of the pier from 8 to 12 ft. below the deck. Most of the piers examined were equipped with timber pockets, metal lined, although the pier of the Virginian Railway at Sewells Point in Norfolk has metal pockets. The upper ends of the pockets are generally about 9 ft. long, and from 5 to 9 ft. wide, the sides and bottom tapering to an opening at the side of the pier about 4 ft. 6 in. wide and from 2 ft. 6 in. to 3 ft. high. In general, pockets are not designed for the storage of coal; Pier No. 3 of the Norfolk and Western Railway at Lamberts Point and the pier of the Virginian Railway at Sewells Point in Norfolk Harbor, however, have gates at the outlets, and are used occasionally for temporary storage.

It has been observed that operation on a number of piers would have been greatly facilitated had the pocket tops been made longer and wider, so as to receive the full discharge of coal from either a hopper or gondola car, and these pocket tops should preferably be made at least 12 ft. long and 9 ft. wide.

Pockets of timber lined with metal are not as durable as those of metal alone, even though the metal be of the same thickness in each case, because water gets between the metal lining and the wood, causing very rapid deterioration of both.

Quite a number of pockets are defective in their design, inasmuch as they do not permit of a free flow of coal through the openings to the chute, because the leads to the chute are constructed in such a manner as to choke the flow of the coal, thereby requiring manual labor to break the jam. A pocket which will permit the coal to flow freely should have no sharp corners, but be constructed on lines of curves rather than angles. The slope of the bottom should be from 40 to 45°, preferably 45°, and the lead to the chute should be designed so that it will not form a wedge at the pocket outlet.

Coal Chutes.—The various types of chutes used on piers for delivering coal to vessels may be divided into four general types:

(1) Simple hinged chutes,

(2) Hinged chutes adjustable at the upper end,

(3) Hinged chutes with telescopic leg at the upper end,

(4) Chutes with telescopic leg at the lower end.

Some of these types are patented, and have different trade names, according to the notions of the patentees, but the foregoing general classification will best serve the purpose of this paper. Fig. 7 contains sketches showing the general characteristics of the four types. A description follows:

Type 1.—Simple Hinged Chute.—This is the simplest type, and is installed on the majority of piers having a number of chutes along the side. The chute is of metal, or of timber with a metal lining. It is hinged to the coal pocket outlet, may be swung to any desired vertical angle about the fixed horizontal hinge, and in some cases has been designed with a pivot arrangement to allow a lateral swing also. The coal drops freely from the outer or lower end of the chute into the hold of the boat. The dimensions of these chutes are dependent to a large extent on the general size of the pier and the class of vessels coaled, and are largely based on the judgment of the different designers, but the most common dimensions are approximately as follows: width at hinge 5 ft. 6 in., width at lower or free end 4 ft. 6 in., depth at hinge 18 in., depth at lower or free end 10 in., the length varies from 12 to 30 ft. On several piers chutes of this type are counterbalanced by chains or cables attached to hanging weights, the counterweight chain or cable being operated over a differential drum fastened to the drum shaft of the operating winch. Chutes of this type are operated by hand winches, and in general, when not counterweighted, it requires the services of one man for about 5 min. to lower and adjust a chute from its full vertical position to the position ready to discharge coal into a vessel, and it takes four men about 5 or 6 min. to raise a chute to its full vertical position. When the chutes are counterbalanced or over-counterweighted, these operations may be accomplished by a less force and in less time. The general design indicated by Type 1, Fig. 7, is typical, but there are a number of modifications for handling and counterbalancing, all more or less effective, some of which are patented.

Type 2.—Hinged Chute Adjustable at Upper End.—This chute is a simple apron essentially as described for Type 1, but its upper end is hinged to a metal frame which slides through a vertical guide attached to the frame of a fixed vertical leg. The chute receives the coal directly from the vertical leg, which is fed from the pockets. The

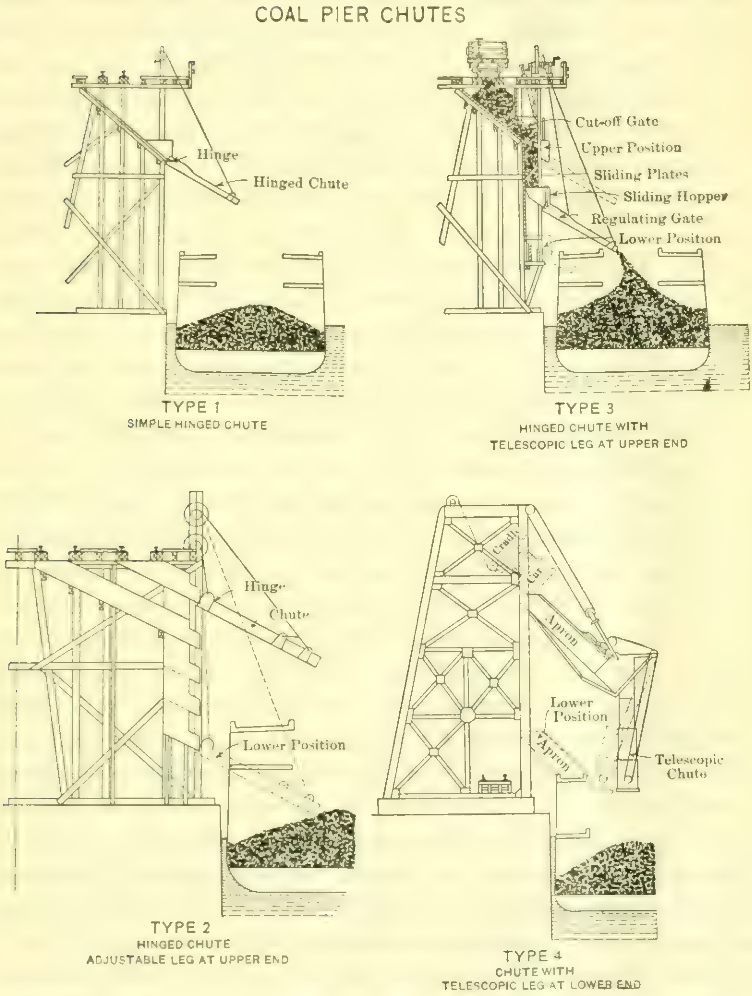

COAL PIER CHUTES
Hinge
Hinged Chute
TYPE 1
SIMPLE HINGED CHUTE
Cut-off Gate
Upper Position
Sliding Plates
Sliding Hopper
Regulating Gate
Lower Position
TYPE 3
HINGED CHUTE WITH
TELESCOPIC LEG AT UPPER END
Hinge
Chute
Lower Position
TYPE 2
HINGED CHUTE
ADJUSTABLE LEG AT UPPER END
Cradle
Car
Apron
Lower Position
Apron
Telescopic Chute
TYPE 4
CHUTE WITH
TELESCOPIC LEG AT LOWER END

Fig. 7.

vertical leg is of metal, or wood with metal lining, and has several regularly spaced openings for discharge into the chute. Each of these openings is provided with a hinged plate which can be swung into a vertical position to close the opening in the side of the vertical chute, or down into an inclined position to form a floor for the vertical leg at the opening from which it is desired to discharge. This type allows a vertical adjustment of the apron, so that coal can be delivered to the hatches of boats without too great a drop from the outer end of the apron. It is known as the Henkel patent. The vertical adjustment of the upper end, and the adjustment of swinging the apron through its vertical angle are both made by hand winches. This chute is sometimes counterweighted for both the upper and lower ends, in a manner similar to that for Type 1. The power necessary to handle and adjust this type is considerably more than for Type 1, as it requires two men about 5 or 6 min. to lower the upper end of the chute from the highest to the lowest pocket outlets, and four or five men from 12 to 20 min. to reverse the movement. In addition to this, it takes about the same number of men and the same time to swing the apron through its vertical arc, as described for Type 1. Type 2, Fig. 7, illustrates this chute. It is used on the piers of the Philadelphia and Reading Railroad at Port Richmond in Philadelphia Harbor.

Type 3.—Hinged Chute with Telescopic Leg at Upper End.—This chute is a simple apron, as described for Type 1, but its upper end is hinged to a vertical telescopic leg, which receives the coal directly from the pocket and discharges into the inclined chute. The front or slip side of the vertical leg is open, and a movable hopper, to which the apron is hinged, can be adjusted vertically throughout the length of the leg. A series of sliding plates, resting on the top of the movable hopper and sliding in guides in the front face of the leg, closes the front face of the vertical leg as the hopper is lowered. The leg being adjustable as to vertical height, and the inclined chute being hinged thereto, makes it more flexible than either Types 1 or 2, and though the coal falls freely from the outer end of the inclined chute, the height of the fall can be reduced or increased by adjusting the vertical leg. These chutes are operated by hand winches, and the time and number of men required to lower and raise the inclined chute are the same as for Type 1; and, in addition, it requires one to two men from 5 to 10 min. to adjust the movable hopper from the highest

to lowest positions, and from four to five men from 10 to 30 min. to reverse this latter operation. These chutes are generally all of metal, and in most cases both the inclined and vertical chutes are counterweighted. This type is patented and generally known as the Link Belt Chute. It is illustrated by Type 3, Fig. 7. They are used on Pier No. 6, Pennsylvania Railroad, at Greenwich, Philadelphia Harbor, Curtis Bay pier and Port Covington pier, in Baltimore, and the Virginian Railway pier at Sewells Point, in Norfolk. The inclined chutes on the Sewells Point pier are pivoted so as to allow the lower end of the chute to swing through a horizontal arc of 12½ ft. on each side of the center line, or a total of 25 ft.

Type 4.—Chute with Telescopic Leg at Lower End.—This type consists of a vertical telescopic chute attached to the outer end of an inclined apron. The coal slides down the apron into the vertical chute and into the hold of the vessel. It is of metal, the lower end of the inclined apron being covered and the lower end of the vertical telescopic chute having a gate so that the chute can generally be kept full of coal in order that it will flow in an unbroken stream from the lower mouth of the chute without excessive fall. The vertical telescopic leg is generally pivoted to the apron near its upper end, so that the lower end can be swung to deliver to the sides as well as to the middle of the hold, and in this way save in the amount of trimming. Generally, the vertical leg is adjustable through a range of 13 ft., and, in addition, the apron is adjustable through a vertical range of 32 ft., so that the arrangement is readily adapted for any reasonable depth of hold or height of hatches. This chute, being very heavy, requires mechanical power for its operation. A number of the mechanical plants in New York Harbor are equipped with chutes of this type. Type 4, Fig. 7, indicates its general construction and adaptability.

These four general types embrace all the chutes now in use on piers on the Atlantic Seaboard. There are numerous modifications, however, some of which have been put into actual use on coal piers in some of the Great Lake ports. A modification of Type 1 is shown on the sketch of the car dumper, Fig. 4. This is a simple hinged chute with a telescopic extension at its lower end.

The movable tower, Fig. 4, is a modification of Type 4, to the lower end of which has been added a horizontal arm capable of being swung in a horizontal arc, which distributes the coal to any part of the hold.

The device is known as an automatic trimmer, but, as far as the writer can ascertain, it has not yet been used.

In general, the height of the pier and the design of the chutes are to a great extent, the limiting factors for any one pier, because, on the height of the delivery end of the chute depends the size of the boats that can be coaled at that pier, without excessive costs for handling the coal. It is usually recognized that the angle of repose for anthracite coal is about 27° with the horizontal and for bituminous coal about 35° with the horizontal, and the chutes should be designed to discharge to the boats so that the delivery end will allow a free flow into the hold without requiring shoveling in the chute, and this will necessitate an inclination of the chutes of somewhat greater angles than those mentioned. Tests show that coal flows on metal chutes at a less angle in summer than in winter, and, in general, the inclination of the chute should never be less than 35° for bituminous, and that the best results are obtained when the chutes are inclined from 40 to 45 degrees.

Relative Merits of the Four Types of Chutes.—The qualities which determine the relative merits of the several types used on gravity plants are:

(1) Simplicity of mechanism and adjustment,
(2) Area of distribution,
(3) Speed of delivery,
(4) Quantity of breakage,
(5) Cost of installation,
(6) Cost of operation,
(7) Cost of maintenance.

The fixed-hinge chute, Type 1, has the merit of simplicity, speed of delivery, and relatively low cost of installation and maintenance. Its area of distribution is generally contracted. The cost of distributing after delivery into the hold, and the damage of the coal due to excessive breakage, may offset, to a large extent, the merits which it possesses. This type, however, is used on a large majority of piers. The cost of a metal chute, erected in place, with counterweight and winches, will vary from \$800 to \$1 000.

The hinged chute, adjustable at the upper end, Type 2, and the hinged chute with telescopic leg at the upper end, Type 3, have the

merit of distributing delivery and small breakage, but the greater cost of installation, operation, and maintenance may offset their merits, to some extent, depending on the commercial conditions under which the coal is handled. The complete cost of this type, connected to the vertical legs on the pier, varies from $1 500 to $1 600.

A number of devices have been patented and tried on the ends of fixed chutes, with an idea of reducing the breakage of coal, giving a greater distribution for gravity piers, but most of them have been discarded because they were cumbersome and slow, or wore out quickly; in cases where they have been meritorious they have been discarded on account of lack of interest by the pier management, which may have felt that the quick release of vessels, a large daily tonnage, and consequent reduction in pier operating expenses, will be more important to the railroad interests than the loss in the value of the coal to the customers due to the breakage. The question is really a commercial one for each pier, as to whether the railroad's interests are or are not best served by the increased expense of installing and maintaining chutes which deliver the coal with the least breakage.

The chute with the telescopic leg at the lower end, Type 4, because of its weight, is adaptable mainly to mechanical plants or on gravity piers equipped with mechanical power for handling the chutes. This type has the merits of wide distribution, speed, and least breakage; but, for gravity piers, has a high cost of installation, operation, and maintenance, and is cumbersome in handling. The merit of distributing the coal over a considerable area, thereby reducing the cost of hand trimming is a commercial factor to be weighed against the cost of installation and of maintenance and power for operation.

On account of the varieties of bituminous coal handled from piers, different arrangements have to be provided in the various ports. In Norfolk Harbor the coal handled is the Pocahontas variety, nominally hard and lumpy, with little dust. It may be dropped from greater heights than is permissible for other varieties, and will not be badly broken. On account of breakage, particular care has to be taken in ports where soft grades of coal are handled, especially for foreign shipments.

Track Scales.—Track scales are provided wherever the business requires that the coal be weighed. They are placed at a practical location on the delivery track on the ground or pier, or at the entrance

of the load yard. Empty cars are seldom weighed, but when necessary, this may be done on the general yard scales. There is only one pier where a scale was installed on the empty return track to weigh empty cars, and it has been abandoned.

In most cases the scales are located so as to require the least shifting of the cars, and be convenient for observation and the concentration of the clerical forces. Their lengths are such as to meet the requirements of the standard length of cars used, the running speed while being weighed, and whether cars are weighed while coupled or while moving singly. The standards in use by the various roads vary from 32 to 60 ft. for scales not fitted with automatic weighing devices, and from 34 to 46 ft. for those fitted with such apparatus. On the two new piers now in course of construction in Norfolk Harbor, scales 68 ft. long, with automatic weighing devices, are contemplated. The weighing capacities of the scales on the piers and in the yards in the various ports vary from 160 000 to 300 000 lb. About one-half of the scales investigated were equipped with automatic weighing devices.

Scales must have unyielding foundations, ample strength, and capacity in excess of the ordinary requirements, in order to withstand the constant use and vibrations without having their accuracy destroyed.

Power Incline Mechanism.—The equipment for a power incline usually consists of a couple of boilers, an engine, and a cable running over pulleys and drums generally attached to what is called a mule, which is arranged so as to push the car up the incline to the deck. In one instance—the pier of the Virginian Railway Company at Sewells Point, Norfolk Harbor, electrical power is used instead of steam. Some of the power inclines are not equipped with a mule, but a cable is attached directly to the front end of the car, which is pulled up instead of being pushed. The mule arrangement is considered safer for operating purposes, and requires less inspection of the drawbars and car mechanism than the cable haul. The complete mechanical equipment, installed, will cost about $17 000 for a 16% incline, or $25 000 for a 25% incline.

Coal-Thawing Plants.—Three types of plant for thawing frozen coal are in use. One is simply the thawing of coal in cars while on the pier deck or in the yard by steam jets inserted in the coal, steam being furnished from a locomotive or from independent boilers. In the second type the coal is also thawed by jets of steam, but the plant is

installed permanently in sheds. The third type is somewhat elaborate, the coal being thawed under cover by hot air.

As thawing is required only during severe weather, and then possibly only for short seasons, it is, at a number of piers, not considered of sufficient importance to justify the expense of installation, and in such places frozen coal is broken by hand.

There are nine plants of the first type, located at Elizabeth, Hoboken, Weehawken, and Guttenberg, in New York Harbor, Greenwich port, in Philadelphia, Port Covington, in Baltimore, and Lamberts Point, Sewells Point, and Newport News, in Norfolk Harbor. There is one of the second type at Edgewater, and one of the third type at South Amboy, in New York Harbor.

Construction.

The construction of most gravity piers is of a temporary character, and consists of pile foundations and framed timber superstructure. Judging from the fact that a large number of these piers do not at present meet the increased requirements, their temporary character of construction was apparently justified. Some of the more modern ones, however, such as those at Sewells Point and Lamberts Point (Piers Nos. 2 and 3), Norfolk Harbor, are constructed in a permanent manner over the length of the dock, but such construction was practically made necessary because of their great height and large capacity. The piers under construction by the Norfolk and Western at Lamberts Point, and the Chesapeake and Ohio at Newport News will also be of permanent construction.

As the cargoes, operating conditions, and possible future developments are at present better understood, the modern pier, in order to meet existing conditions and anticipated developments, should be built in a more permanent manner than heretofore, so as to secure the necessary stability under the more severe operating conditions and as a precaution against danger of destruction by fire.

Operation.

The direct cost of operating a pier includes clerical force, policing, engine service, expenses for running the machinery, and the labor of dumping cars and trimming coal. The items of interest on investment, maintenance of plant, and depreciation are also proper charges which affect materially the cost of handling coal, and though not herein con-

sidered part of the operating expenses, they are fully accounted for under the heading, "Relative Merits of Different Classes and Types." The items of expense due to general office, supervision, yard, and tugboat service have not been considered in this paper, as they have no important bearing on its object.

Clerical Force and Policing.—The expenses of office force and policing vary somewhat with the capacities of the plants. On one gravity plant investigated these charges in 1911 amounted to $8 068 for clerical force and $1 416 for policing, a total of $9 484 for an output of 2 078 321 tons, making an average cost per ton of about 0.46 cent. During that year the pier worked to about 90% of its estimated average capacity, or at the average rating of 180 cars per day for 270 days. If it had worked to its full average capacity of 180 cars for 300 days, the cost per ton would have been about 0.42 cent, and if it had worked to a capacity of 200 cars per day for 300 days the cost per ton would have been 0.38 cent. This cost of 0.38 cent per ton, therefore, may be considered a reasonable charge for clerical force and policing on a pier working to a normal capacity of 200 cars per day. When working to 75% of the normal capacity, the cost would be about 0.50 cent per ton.

Engine Service.—A locomotive incline type of pier working to an average capacity of 200 cars per day requires the constant use of one locomotive for pushing the cars from the yard to the pier deck. The average charge for an engine which will do the work effectively will approximate $43 per day, the cost being made up of the following items:

Repairs	$10.94	
Miscellaneous expenses	1.64	
Interest on cost, $13 500 at 5%	1.85	
Depreciation " " "	1.85	$16.28
Coal, 8 tons at $1.00	$8.00	
Lubrication	0.24	
Water	0.77	
Other supplies	0.31	
Engine-house expense	0.70	10.02

One engineer............................	$4.00	
One fireman............................	2.50	
One conductor............................	3.60	
Two brakesmen at $3.30 each...............	6.60	16.70
Total daily charge against operation........		$43.00

This engine service would amount to $12 900 per year of 300 working days, or about 0.51 cent per ton, on the basis of an average car load of 42 tons. For piers of the barney incline type, or mechanical type, where the yard is arranged so as to permit the loaded cars to drift by gravity from the yard to the barney pits, no engine service will be required, but, when not thus arranged, one engine will be required for bringing the loaded cars to the barney, at a cost of 0.51 cent per ton.

Expenses of Operating Machinery.—On the power incline type of pier, with a 22% grade, and developing a capacity of 200 cars per day, the daily charges for operating the haulage system (not including dumping cars or engine service) will be about as follows:

Coal, 6 tons at $2.50............	$15.00	
Oil, water, light, etc............	3.25	$18.25
One engineer....................	$4.00	
Two firemen at $2.40.........	4.80	
Two signal men " 2.00.........	4.00	
Four car riders " 2.00.........	8.00	
One general man " 2.40.........	2.40	23.20
Total daily charge..................		$41.45

This is equal to a cost of 0.49 cent per ton. If the plant should work to only 75% of its average daily capacity, the cost per ton would be about 0.60 cent, assuming that only the coal consumption is reduced.

On a modern mechanical car dumper, operated by steam, with an average capacity of 200 cars per day, the daily cost for operating the machinery, including dumping cars, but exclusive of the engine service, will be about as follows:

Coal, 15 tons at $2.50............	$37.50	
Oil, water, incidentals, etc........	8.00	$45.50
One engineer....................	$4.00	
Two firemen at $2.40............	4.80	
One cradle and apron operator....	3.00	
One car handling machinery.....	3.00	
One chute operator..............	2.50	
Four car riders at $2.00..........	8.00	25.30
Total daily charge..................		$70.80

This is equal to a cost of 0.84 cent per ton. If the plant should work to only 75% of its average daily capacity, the cost per ton would be about 0.98 cent, assuming that only the coal consumption is reduced.

Labor of Unloading Coal.—On gravity piers, with a maximum capacity of 300 cars per day and an average of about 200 cars per day, it requires about eight gangs of eight men each on the deck, and one general foreman, for unloading 8 cars at a time into boats in two slips. It takes one gang about 2 min. to dump a car of coal, under the most favorable conditions, and as many as 45 min. when the coal is frozen. In general, 3 cars per chute per hour is considered good work.

On some piers the unloading of the coal after the cars are placed on the deck is done by agreement with the men on the basis of a unit price per car. At a pier in New York Harbor, average capacity 150 cars per day, a car of any size is unloaded for $1, or at about 2.38 cents per ton. At a pier in Philadelphia Harbor, average capacity 100 cars per day, cars are unloaded at the following rates:

60 000-lb.	wooden gondolas,	$1.00 = 3.73	cents per gross ton.
100 000 "	self-dumping cars,	1.50 = 3.36	" " " "
115 000 "	steel gondolas,	2.00 = 3.88	" " " "

On a pier in Baltimore, average capacity 180 cars per day during 1911, the cost for labor alone in dumping cars was 1.89 cents per ton. This may also be considered a reasonable price for a pier of the locomotive incline type, working up to a normal capacity of 200 cars per day, and the cost will be the same for a pier of the power incline type. For mechanical plants which dump the cars bodily, the cost of unloading is included in the cost of handling the plant.

Trimming Coal.—Trimming is usually paid for by the hour, and

the cost will depend largely on the ruling wages, the type of chutes on the pier, and the character of the vessels loaded. For simple hinged chutes, which practically do no distributing, there is necessarily more trimming than for those which are telescopic and adjustable. The cost of trimming for one large plant in Baltimore Harbor during 1911 was 3.42 cents per ton. In general, where trimming is done under agreement with stevedore companies, the price per ton is about:

3 cents for open-top boats, such as barges and lighters,
5 " " single-deck boats,
7 " " large double-deck colliers.

In mechanical plants with the ordinary car dumper, and telescopic chute at the lower end, the amount of hand trimming is estimated at about 90% of that required when boats are loaded from gravity plants. Mechanical trimmers attached to the lower end of the telescopic leg would probably require only 75% of the amount.

For estimating purposes, in connection with 200-car average daily capacity piers, when coaling to all classes of boats, the following costs per ton for trimming will represent fairly well the average prices:

(a) Gravity piers, chutes having adjustable legs...3.42 cents.
(b) Car-dumping machines with telescopic chute..3.08 "
(c) Car-dumping machine with mechanical trimmer.2.56 "

Summary.—Reasonable and fair charges per ton for the operating expenses of locomotive incline type, power incline type, and car-dumping type of plant, each working to its normal capacity of about 200 cars per day, and when yard grades are such as to permit the gravity delivery of cars from the load yard to the barney pits without engine service, are given in Table 10.

TABLE 10.—Charge per Ton for Operating Expenses for Various Plants; Full Normal Capacity.

Items.	Locomotive incline.	Power incline.	Car-dumping machine.
	Cents.	Cents.	Cents.
Office and policing	0.38	0.38	0.38
Engine service	0.51	....	...
Labor and fuel for machinery	....	0.49	0.84
Unloading cars	1.89	1.89	....
Total, exclusive of trimming	2.78	2.76	1.22
Trimming coal	3.42	3.42	3.08
Total, including trimming	6.20	6.18	4.30

In case the piers should work only to about 75% of their normal capacities, which is nearer actual practice, the operating charges per ton, other conditions being the same as above, will be as given in Table 11.

TABLE 11.—Charge per Ton for Expenses when Operating to 75 Per Cent. of Normal Capacity.

Items.	Locomotive incline.	Power incline.	Car-dumping machine.
	Cents.	Cents.	Cents.
Office and policing	0.50	0.50	0.50
Engine service	0.51	....	....
Labor and fuel for machinery	....	0.60	0.98
Unloading cars	1.89	1.89	....
Total, exclusive of trimming	2.90	2.99	1.48
Trimming coal	3.42	4.32	3.08
Total, including trimming	6.32	6.41	4.56

In cases where engine service is required for bringing the loads from the yards to the barney of barney-incline and car-dumping plants, the cost of such service should be added to that of operating either the barney-incline or car-dumping types, and under such conditions, the operation cost per ton for the three types would be as given in Table 12.

TABLE 12.—Operating Costs.

	Locomotive incline.	Power incline.	Car-dumping machine.
A.—Plants Working to Full Normal Capacity.			
	Cents.	Cents.	Cents.
Operation, exclusive of trimming	2.78	3.27	1.73
Total, including trimming	6.20	6.69	4.81
B.—Plants Working to 75 Per Cent. of Normal Capacity.			
Operation, exclusive of trimming	2.90	3.50	1.99
Total, including trimming	6.32	6.92	5.07

The charges for interest, maintenance, and depreciation also enter into the cost per ton for handling coal, and are considered in connection with and under the heading "Relative Merits of Different Classes

and Types." Therefore, the operating costs alone, as contained in the foregoing tabulations, should not be considered as representing the relative economy of the different plants.

Relative Merits of Different Classes and Types.

Each type of pier herein described has certain features which may give it a preponderance of merit for that particular location and those special service requirements for which it is best adapted. Therefore, the relative merits of the different types should not be judged independently of a consideration of the particular local situation and requirements which the construction of the plant will have to meet.

In every case, however, where the local conditions will permit of the adoption of a gravity, mechanical, or combination type, the relative merits should be measured by the relative efficiencies for the location considered. For a proper determination of these efficiencies the following items must be examined:

(1) Discharging capacities,

(2) Ability to make simultaneous deliveries to several vessels,

(3) Relative freedom from possible breakdown which will seriously delay operation,

(4) Relative breakage of coal during delivery,

(5) Cost of plant,

(6) Interest on cost,

(7) Depreciation of plant to be taken care of by an annual fund drawing compound interest, which will amount to a sufficient sum to renew the various parts of the plant at the end of their estimated serviceability period,

(8) Cost of operation, which includes cost of handling and dumping cars, policing, office expenses, engine service, expenses for operating machinery, trimming, etc.

Items 6, 7, and 8, representing interest, depreciation, and operation, are the annual charges in connection with the plant, and, when stated in terms of cost per ton of coal output, the relative cost per ton for the different types will represent their relative economy. The plant which may have the merit of greatest economy in cost per ton of coal output, may be deficient to such an extent in regard to capacity, simultaneous delivery to several vessels, possible breakdown, and coal breakage, as to offset its apparent economy; therefore, all the eight

items mentioned, and not merely apparent economy, should be fully considered when determining the relative merits of different types for a particular location.

Relative Economy.

For the purpose of determining the relative economy of a locomotive incline of Type A6, a power incline of Type A8, and a mechanical car dumper of Type B2, detailed estimates have been prepared covering:

(1) Temporary construction, namely, pile and timber work as far as practicable, that exposed in water being treated.

(2) Partly permanent construction, namely, trestle approaches, bulkheads, barney inclines, and empty return trestle for mechanical plants, of pile and timber construction as far as practicable; and the pier substructure and superstructure, from the bulkhead to the sea end, with the exception of barney and return trestles for mechanical plants, of steel and concrete as far as practicable.

(3) Permanent construction, namely, all parts, including approaches, to be of steel and concrete as far as practicable.

These estimates include everything except right of way, grading, and tracks, and are based on the following assumptions:

(1) Local Conditions.—Local conditions suitable for the construction of an economical design of each type, the grade in the load yards being such as to give gravity delivery of loads to the foot of the barney incline for Types A8 and B2 plants, thereby not requiring engine service for this purpose.

(2) Normal Average Capacity.—The normal average capacity of each plant to be 200 cars per day for 300 days per year, or an annual output of 2 520 000 gross tons, based on the average of 42 tons per car.

(3) Dimensions.—For locomotive and power incline types: length from bulkhead, 500 ft.; height above mean tide, 60 ft.; width at lower deck, 70 ft.; two slips, each 500 ft. long, 200 ft. wide, and 30 ft. deep.

For mechanical car dumper: pier length, 800 ft.; width, 55 ft.; only one slip, 800 ft. wide and 30 ft. deep.

(4) Tracks and Grades.—Locomotive incline: one track, 3% grade; pier deck, 2 tracks, 1% grade; empty return, one track, about 2% grade.

Power incline, Type A8: one track, 20% grade; pier deck and empty return, same as for locomotive incline.

Mechanical car dumper: barney incline; one track on 12% grade, and empty return over track on grade varying from 2 to 1 per cent.

(5) *Cost of Plant.*—Present average ruling prices.

(6) *Interest on Investment.*—5% annually.

(7) *Depreciation.*—The assumption is made that at the end of 25 years the conditions will have changed to such an extent as to necessitate the re-design and construction of all temporary work and machinery, and at the end of 50 years all permanent work, except dredging in slips. The charges for this depreciation are taken care of by an annual renewal fund drawing compound interest at 4 per cent.

(8) *Maintenance Charges per Annum.*—

Temporary work.—	Pier substructure and bulkheads..	5%
	Pile foundations in approaches...	5%
	Untreated framed timberwork...	10%
Permanent work.—	Steelwork	2%
	All other construction..........	1%
Machinery.—	Power incline, car dumper, scales, chutes, etc................	10%
Dredging.—	....	1%
Operation.—	From Table 12.	

TABLE 13.—COMPARATIVE ESTIMATES OF COST.

Type of pier.	Cost of plant.	Cost per Ton of Coal, in Cents.						Total charges per ton.
		Int.	Depr.	Maint.	Operation.			
					From deck.	Trim.	Total.	
Temporary Construction.								
Loco. incline, A6................	$307 720	0.61	0.25	0.76	2.78	3.42	6.20	7.82
Power incline, A8...............	299 280	0.59	0.24	0.74	2.76	3.42	6.18	7.75
Car dumper, B2.................	279 640	0.55	0.22	0.66	1.22	3.08	4.30	5.73
Partly Permanent Construction.								
Loco. incline, A6................	373 790	0.74	0.18	0.56	2.78	3.42	6.20	7.68
Power incline, A8...............	365 350	0.72	0.17	0.54	2.76	3.42	6.18	7.61
Car dumper, B2.................	334 640	0.66	0.16	0.52	1.22	3.08	4.30	5.64
Permanent Construction.								
Loco. incline, A6................	431 400	0.86	0.12	0.37	2.78	3.42	6.20	7.55
Power incline, A8...............	395 980	0.79	0.13	0.41	2.76	3.42	6.18	7.51
Car dumper, B2.................	340 260	0.67	0.14	0.47	1.22	3.08	4.30	5.58

The results of the estimates are summarized in Table 13, which shows the relative economy of the different types and kinds of construc-

tion, in terms of the total cost per ton of coal output, and when based on the assumed conditions.

It will be observed that, under the assumed conditions:

(a) The mechanical car-dumper type will not only be the least expensive in first cost, but is also by far the most economical in total charges per ton of coal output;

(b) The power incline type is somewhat less expensive in first cost than the locomotive incline, and is also a little more economical in total cost per ton of coal output;

(c) That though the permanent construction, for any of the three types, will necessarily cost more than temporary or partly temporary work, it shows more economy in the total cost per ton of coal output.

For plants of greater output and greater heights than assumed, the cost per ton of coal will vary from that given in Table 13, but the relative economy of the different types will not be affected materially. If the annual output should be about 75% of that assumed, or, in other words, if the piers should work only 225 days per year instead of 300, as assumed, then the car dumper would still remain the most economical in first cost and cost per ton of coal output, but the locomotive incline, though costing a little more to construct than the power incline, would be more economical than the latter in total cost per ton of coal output.

In the foregoing comparison, although the mechanical car-dumper type, B2, is the most economical of the three types considered, under the conditions assumed, yet it must be remembered that a single car-dumping machine can deliver coal to only one vessel at a time, and, where conditions require simultaneous delivery to several vessels, it becomes necessary to construct at least two machines, in which case economy no longer exists.

A plant similar to Type B4, Fig. 4, which is composed of a fixed car-dumping machine and a movable-tower car-dumping machine would be more expensive in first cost than the car dumper, Type B2, but would cost somewhat less than either the locomotive or power incline of permanent construction. The total cost per ton of coal output would be about 0.5 or 0.6 cent less than for the locomotive or power incline type, about 1.4 cents more than for the simple car dumper, B2, on the

assumption that the chute is not equipped with a mechanical trimmer. Type B4 coals vessels from the tower dumper, which can be moved along the dock to the hatches of a large vessel, or to a number of barges moored to the pier, and the tower can be moved more speedily than the vessels and barges. It will require a pier length of about 500 ft. as compared with 800 ft. for the dumper alone.

Comparison of Combination with Other Classes.

Combinations of car-dumping machines with special cars and elevators or inclined planes for raising the special cars to the upper decks of the piers, such as the proposed Norfolk and Western Pier No. 4 at Lamberts Point, the proposed Chesapeake and Ohio Pier No. 9 at Newport News, and the existing Virginian Railway pier at Sewells Point, are constructed for the purpose of meeting requirements for which the ordinary gravity types and the mechanical dumper alone are not so well adapted, and, therefore, they form a class by themselves for special work. These, of course, can be constructed in locations which also favor the ordinary gravity types or the simple car-dumping machine, but, under such conditions, there is no apparent economy in constructing a combination plant composed of a dumping machine and a gravity pier, when either one alone would serve the purpose.

Selection of a Type of Pier.

The selection of a type of gravity pier should not be made until the relative merits for the local conditions have been fully determined in the manner indicated in the preceding discussion. It is not merely a matter of adopting the plans of some pier which is in operation elsewhere, as the tendency too often prevails at present, but is a matter which involves a most thorough consideration of the dimensions and cargoes of the vessels to be loaded, the required maximum daily capacity, the probable future developments, the local conditions which affect approaches, grades, track layout, etc., and finally the preparation of a design which will meet these conditions economically.

The selection of a type of mechanical plant is also, as in the case of a gravity plant, not merely a matter of fancy or adoption of a type already built, but one of efficiency for conditions to be met, and requires the same careful study of controlling conditions and economy. As a rule, mechanical plants heretofore have not been installed where

conditions are equally suitable for the construction of a gravity plant. There is a feeling, more or less unfounded, against too much machinery, and this feeling prejudices operators against such types; nevertheless, their utility is strongly indicated, and their economy is beyond doubt in certain locations, regardless of the question of individual feelings.

As indicated in the previous discussion, the combination of mechanical car dumpers with gravity piers, such as those in use and under construction in Norfolk Harbor, comprises a special class of plant adapted for service conditions which render the construction of an ordinary gravity plant or car-dumping machine impracticable.

The selection of a type evidently rests on the proper determination of its relative merits in meeting the following conditions:

(1) Free delivery of coal to all sizes and classes of boats which take coal or are likely to take coal in the port under consideration.

(2) The delivery of coal without breakage to such an extent as to be objectionable to the users,

(3) The simultaneous delivery to several vessels on one or both sides if required,

(4) Hourly capacity such as to give prompt release to vessels coaling,

(5) Economical cost per ton of coal output.

It has been shown that the car-dumping machine, Type B2, is the most economical in cost per ton of coal output, but can coal only one vessel at a time. The vessel, if a large one, must be moved so as to bring its hatches within the range of the chute, and must be taken away from the pier before another vessel can coal. These disadvantages should be weighed against its economy, and, where local conditions require the simultaneous loading of several vessels, this type is not suitable unless more than one machine is installed, and this can be done only at the sacrifice of considerable economy.

It has also been stated that the mechanical plant, Type B4, composed of a fixed car dumper and a movable-tower car dumper, though not as economical as the fixed car dumper alone, is more economical in cost per ton of coal output than either the locomotive or power incline types. It has the advantage of coaling simultaneously to two boats, one of which may be a large collier, and both boats may be kept

moored to the pier while being coaled. There are no plants of this type in operation, as far as the writer knows, but it is a practicable type and worthy of consideration.

It has also been shown that, when the yard can be constructed on such grades as to feed the coal cars to the barney pits, the barney or power incline type is slightly more economical than the locomotive incline type, but, if the local conditions are such as to require a locomotive for delivering the coal cars from the yard to the barney, then this type is not as economical as the locomotive incline type, but it has an advantage in many locations where the space back of the bulkhead is contracted.

As a general proposition, where the location will permit of its construction, and vessels coaling cars are of moderate height, and where the capacities are between 20 and 30 cars per hour, the locomotive incline type has proved more satisfactory than any of the others, on account of the simplicity of its construction and freedom from heavy or complicated machinery.

Proper Design and Construction.

After having determined which type of pier has a preponderance of merit for the local situation and the conditions under which it is to be operated, it should be designed and constructed in such a manner as to obtain the greatest possible efficiency and economy consistent with the type selected.

The best results cannot be obtained by copying the plans of some similar pier, because most piers thus far designed have defects which impair their efficiency, and though in some cases the defects of design have been remedied after the piers have been placed in service, the original plans in all probability remain unchanged.

The proper determination of heights, lengths, widths, number of tracks, grades, switchbacks, construction of bins or pockets and chutes, etc., though usually considered as details of the design, are just as essential for the effective operation of the plant as the proper design of the carrying parts is for the safety of the structure.

All the so-called details have been rather fully discussed herein, and therefore a repetition is not necessary. The salient points, however, may be briefly summarized, as follows:

(1) The height of a gravity pier above mean tide should be from 33 to 43 ft. above the highest hatches of vessels coaling at the port, and will depend on the type of chute and the storage capacity of the bins.

(2) The length from the bulkhead to the sea end of a gravity pier should be not less than about 700 ft., in order to accommodate Government colliers and the probable future steamers of the New England Coal and Coke Company.

(3) The least practicable width for gravity pier coaling from two sides is about 70 ft.

(4) Grades on locomotive inclines should preferably not exceed 3%; on barney inclines to gravity piers, 18%; on barney inclines to mechanical plants, 12%; and on empty return tracks, 2 per cent. Grades for gravity movement of loads should preferably be not less than from 0.8 to 1.25%, depending on southern or northern location. All changes in grades should have easements.

(5) Switchbacks are preferable to pivot tables, and should be constructed so that grades may be readily adjusted to meet varying conditions of weather and temperature.

(6) Tops of pockets or bins should have a length of at least 12 ft. and a width of at least 9 ft., for receiving coal from either a hopper or gondola car. The slopes should be not less than 40° from the horizontal, and preferably 45°, with leads to the chute designed so that they will not form a wedge at the pocket outlet. A pocket free from sharp corners, and constructed on lines of curves rather than of angles will permit the coal to flow more freely.

(7) Metal chutes with adjustable legs at the pier connection, or a similar type, are superior to the simple hinged chute. Where electric power is available, and the pier has a large output to cargoes of various sizes, the adjustments should be controlled by motors. For a free flow of coal, the inclination of the chute from the horizontal should be about 40° for bituminous coal. Chutes with telescopic legs at the discharging end cause less breakage of coal than other types, and require less trimming.

The question as to whether the construction shall be temporary, partly permanent, or wholly permanent is one of policy, to a large extent. In most of the piers, both substructures and superstructures are of temporary construction, and all gravity piers thus far built are of temporary construction back of the bulkhead. Temporary work is the least expensive in first cost, but is less economical than either partly permanent or wholly permanent construction, as the total cost per ton of coal output will be the highest when interest, depreciation, and maintenance are taken into consideration.

A pier should be properly designed, not only to meet requirements as to normal and maximum hourly output, but also the very probable general increase in cargoes, and the capacity and weight of coal cars. Mechanical car dumpers are now designed for handling coal cars of 100 tons capacity. The construction, therefore, no matter whether temporary or permanent, should by all means be substantial and simple in character, and, in most cases where piers will probably meet conditions for a period of 25 years, it will be true economy to construct all work from the bulkhead to the sea end, for both substructure and superstructure, in a permanent manner, even if the approach trestlework and empty return be of temporary construction.

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PAPERS AND DISCUSSIONS

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TOPOGRAPHICAL SURVEYS MADE BY THE AMERICAN SECTION OF THE INTERNATIONAL BOUNDARY COMMISSION UNITED STATES AND MEXICO.

By W. W. Follett, M. Am. Soc. C. E.

To be Presented December 3d, 1913.

Introduction.

During the winter of 1910-11, the International Boundary Commission between the United States and Mexico, of which the writer is Consulting Engineer for the United States and Mr. E. Zayas for Mexico, made a survey of the Rio Grande from Roma to the Gulf of Mexico. This survey covered an area about 140 miles long and from 2 to 3 miles wide, including within its limits the territory which is subject to the erosive action of the river. The purpose of the survey was to obtain data from which a map could be made on a scale of 1 in 5 000, which would be accurate as to general dimensions and the location of fixed points, and would show, within reasonable limits, the location of the topographical features.

The country traversed was practically a level plain with an escarpment, from 1 to 3 m. high, on each side of the river, which marked the limit of ordinary overflow and also, approximately, the margin

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

of the erosive area of the river. These escarpments were from less than 1 mile to 2 miles, and, in extreme cases, 3 miles apart. Practically the whole area between them has been at some time, or may be in the future, the bed of the river. There were no hills suitable for triangulation. The main wagon road on the north side of the river was, for the greater part of the way, on the bench above the limit of the overflow line. There was a thick cover of brush and trees on three-fourths of the area to be surveyed.

It was the purpose of the survey to locate all old channels and breaks in the surface between the two escarpments, including, of course, the river, with its high and low banks, all wagon roads, towns, ranches, irrigation or drainage ditches, levees, railroads, etc., both below and above the escarpments, within the limits of the map, together with a sufficient number of elevations to locate meter contours.

The river has cut off many bends, forming what are locally known as "bancos." Around these, the Commission, at various times, has laid traverses which mark, approximately, the center of the old channel abandoned by the river when it cut off the banco. These traverses form the property lines between the owner of the banco and the adjoining mainland proprietors. Their corners are marked by substantial timber posts, and there has been built on each banco a concrete monument to which the traverse is tied. All this work has been done accurately, but, when the field operations began, in the fall of 1910, the different banco surveys were not tied together.

Methods.

The methods used in making this survey were as follows:

First. A precise line was located and measured, which, for the greater part of the way, was along the main wagon road. At intervals of from 2 to 3 miles, small concrete reference points were built and accurately located.

Second. From this precise line spurs were run to the monuments on the bancos.

Third. Stadia traverses were run, starting from, and closing on, some precisely located point, or from and to stadia hubs which had already been tied to precise points.

Fourth. A primary line of levels was run from Roma to the Gulf,

and the elevation of each reference point was accurately determined.

Fifth. Ordinary levels were run to determine the elevation of each hub on the stadia lines.

The precise line, the banco ties and traverses, and the primary levels were run jointly by the two sections (American and Mexican) of the Commission; that is, the work was first done by one section and then checked by the other, the notes were compared, and an agreement was reached between the two consulting engineers. The stadia lines were run independently and the maps compared.

In order that the reader may understand the operations, Plate XCV, a small section of the original 1 in 5 000 map of the American section, is submitted. The original map was printed in colors, so that it is much more easily read than this sample. It also showed meter contours and many elevations which are here omitted, as are also the latitude and longitude and latitude and departure lines, both of which are shown on the original.

The traverses around the bancos (Tahuachal, La Isla, and Tahuachalito) and the lines having angle points marked A, B, or C, were chained. The "A" is the precise line. The T, R, and M points are stadia stations. A study of the lines will show how they were tied together and to the accurately located points—either banco corners or A, B, or C hubs.

The heavy broken lines show the channel of 1897-98. It is taken from a survey and map made by the writer for the Boundary Commission. Comparison of it with the river as found in 1910-11 gives an idea of how much the river shifts by erosion and deposit. East of La Isla, there is seen a banco in the making. In a few years more, possibly only 3 or 4, the river will go through the neck near R-1 569, and a new Mexican banco will be cut to the American side of the river.

The hatched line marked "limit of ordinary overflow," is the escarpment before mentioned. It is an important line, for besides showing where ordinary floods stop, it marks quite closely the erosive limit of the river, and shows a change in soil and vegetation. Below it is recent alluvial deposit with wet-land growth. Above it is considerable clay and a semi-arid growth, such as cactus, mesquite, and other thorny trees and shrubs.

When fully organized, the American section had five transit and two level parties in the field. One transit party laid out and measured the precise line, one ran the banco ties and located some banco traverses which had not been run, one took by stadia the river with its adjoining topography, one obtained Texas topography, and the last one did the work on the Mexican side.

One level party ran the primary level line, carried levels over the river topography hubs, and took rough cross-sections of the river bed opposite each hub. The other one ran levels over the Texas and Mexico topography hubs and hunted high-water marks.

In the office, a computer kept up the computations of the precise line, banco ties, and new banco traverses, referring all by latitude and departure to an assumed initial point in Roma. A draftsman, working at night, platted, by latitude and departure, the precise points, banco ties, and traverses, and, by protractor, the stadia lines which had been run during the day. Another draftsman, working during the day, platted the topography as fast as the books came in. In this way, close check was kept on the work which was being done. Failures to close on stadia traverses were detected at once, and the omission of any topographical features was soon noted.

The survey and map were controlled by the precise line. In computing this, the observed azimuths were corrected by adding 1.6″ for each 100 m. easting, measured from center to center of the courses. This is the amount of the divergence of a parallel of latitude from a straight east and west line in Latitude 26°. By thus correcting the azimuths, the parallels of latitude are represented on the map by straight lines, and the meridians are drawn at right angles to them. Of course, this did not make a correct geodetic map, but represented the surface as being a plane.

With so many parties in the field, setting stakes, it was necessary to have such a system of marking instrument points and keeping notes that no confusion would result. The following scheme was adopted:

The precise line was called the "A" line, and the stakes were marked consecutively from 1. This line was double-chained, the angles repeated, and the latitudes and departures computed in camp, after the azimuths were corrected for easting.

The ties to banco monuments were marked "B," with consecu-


SECTION OF THE
MAP OF THE LOWER RIO GRANDE
SCALE OF METERS
LEGEND
Traverse of Bancos
Precise or "A" Line
Tie or "B" Line
Stadia Lines
UNITED STATES
MEXICO
Brownsville Road
Rosita Ranch
Encantada Ranch
Carmen Ranch
San Pedro Ranch
San Ysidro Ranch
Matamoros Road
Limit of Ordinary Overflow
TAHUACHAL BANCO 1897
TAHUACHALITO BANCO 1861
LA ISLA BANCO 1857
RIO GRANDE
Perm Mon.
International Boundary Line

tive numbers from 1. These lines were double-chained, the angles repeated, and latitudes and departures computed in camp.

Auxiliary closed traverse lines around any of the new bancos were marked "C," with consecutive numbers from 1. As these were closed lines, they were chained only once and the angles were usually measured only once, although they were sometimes repeated. The latitudes and departures were computed in camp.

As the traverses to all bancos had been carefully chained, tied to the permanent monument, and computed, when a man in the field found a banco corner or a hub with a witness stake marked A, B, or C, he knew that he had a point having a known latitude and departure, and that he could tie to it. He also knew that the azimuth of the line, whatever it was, was known within a minute, so that he could check his azimuth.

On the topographical work, every shot was given a number, whether it was a side shot or to a hub. The river stakes were marked "R", the Texas stakes "T", and the Mexican ones "M". To the river were assigned the numbers 0 to 5 000, to the Texas stakes, from 5 001 to 7 500, and to the Mexican ones, from 7 501 to 10 000. When a man used up the numbers assigned to him, he started over again. Surveys for taking the topography of new bancos used numbers from 10 001 up. It followed, therefore, that the number of the stake, even without the letter, showed what line it was on.

In recording instrument points, the original number marked on the stake was always used, no matter how many other lines ran to that point. This prevented confusion, and when a non-consecutive number appeared in the notes, it always drew attention to the fact that a tie of some sort to some previously located point had been made. The rule was followed rigidly, especially when tying to points set by the Mexican Section.

RESULTS.

The first questions which an engineer asks when looking over any work of an engineering nature, are: What methods were used, what results were obtained, and what was the unit cost of the work? The first two questions can be fully answered. As no separate accounts were kept of the different kinds of work, only an approximate answer can be given to the last.

In all the work, joint and otherwise, it was constantly borne in mind that a reasonable degree of accuracy was a desideratum, but that no refinements should be introduced which would add greatly to the cost without increasing the practical value of the work. In the following discussion, the deviation in this respect from the methods sometimes used are fully set forth.

For convenience of ready reference, the limits of error to which it was attempted to work, are given:

Precise Line.—Angles should not be more than 2″ of arc in error. Distances should not differ more than 1 in 20 000, or 5 mm. to the 100 m.

Tie Lines to Bancos.—Angles should check within 20″ of arc (they really checked much closer than this). Distances should not differ more than 1 in 10 000.

Primary Levels.—Elevations should check within

$$0.01 \text{ m.} \sqrt{\text{distance, in miles, between benches.}}$$

Stadia Work.—No definite limit was specified, but, whenever a platted closure was so large as to indicate an error in reading distances, the line was re-run. Roughly, the allowable error in platting was 2 m. to the 1 000. Azimuth should check within 5′ of arc.

Precise Line.

The purpose of the precise line was to furnish a base to which all stadia lines could be tied, and to determine the relative position of the reference points and permanent monuments. It was the intention to make the precise work so accurate that it would take the place of what would be called a secondary triangulation. There was no attempt at extreme accuracy, but care was taken to obtain uniform work, and the best result to be had with an engineer's ordinary No. 1 transit.

The country was peculiarly fitted for chaining, being usually as level and smooth as a floor. This is seen from the fact that, out of 411 courses, on only 26 was it necessary to make corrections for portions of the line for differences of elevation.

The party on the precise line consisted of a transitman and two chainmen, and several laborers who acted as flagmen and axemen. The instrument used was an ordinary Buff and Berger No. 1 transit, made in 1885, with the plate graduated to 20′ and the verniers

reading to 20″ of arc. This instrument had been in ordinary use for 25 years, and had been returned to the makers once for overhauling. A Roe, 100-m. tape was used. It was graduated to meters, with end meters in tenths. A small piece of old steel tape was also carried, in order to read fractions of a meter. A cheap thermometer in a wooden case was used for taking temperatures. The chain lengths were marked by steel pins $\frac{3}{16}$ in. in diameter. The tape was supported throughout, that is, laid smoothly on the ground. The sight poles were ordinary 8-ft. transit rods. Another 100-m., Roe tape was kept in camp and used as a standard. With it the tapes in use by both sections of the Commission were compared frequently.

The programme of work was about as follows: The two chainmen, under the direction of the transitman, with three or four axemen, would go ahead and lay out the line. They usually followed the main road. This was sometimes quite crooked, with dense thorny undergrowth on each side, and it required considerable experimenting to get the transit points in places such that the brush-cutting would be reduced to a minimum and with the proper distance of 100 m. or more between points. No effort was made to obtain very long sights, as it was found that the boiling of the air was likely to be so great that the transit rods could not be seen. Only a few sights were taken which were more than 1 000 m. long; the average length was 584 m. When the chainmen had ranged in a line and cut away enough brush to obtain a sight, a hub, about 2½ in. in diameter and as long as could be forced into the hard ground without brooming, was driven flush with the surface and a hollow-headed tack was put in its center, a witness stake and three guy stakes were driven, and the witness stake was marked with the consecutive number. The line was given the letter A, and the stakes were marked consecutively. A-1 was in the main road near R. P. No. 1, 2 miles above Rio Grande City. From there the numbers ran toward Roma until A-26 was set. Here, a junction with the Mexican line was made on their Z-410 stake, and their numbers were used into Roma where Z-399 was found, from which R. P. "E" was set.

A-27 was set toward Rio Grande City from R. P. No. 1, and it was from A-385 that R. P. No. 55 was set on the shore of the Gulf.

Starting from R. P. "E", there were 12 courses down to A-26; from there to R. P. No. 1 there were 26 courses, and from R. P. No. 1 to

the Gulf there were 373 courses, or a total of 411 courses in all. The reason that the number of courses exceeds the points marked A is that 17 of the reference points and one hub set by the Mexicans and marked M-11 were used as angle points on the A line, and that four A numbers were used on spur lines to reference points. The usual rule was followed of giving a hub only one number, and that the one it first had.

After 3 or 4 km. of line had been located, the axemen were left to finish the clearing, which was done with great care so that the tape would lie smooth and straight, and the chainmen started to measure with the 100-m. tape and 11 steel pins (the surveyor's ordinary number). There were long leather thongs in each end of the chain for holding it. The head chainman carried the forward chaining book, spring balance, and thermometer. When a full chain was reached, the thermometer was laid on the ground face up, in the sun, if it were shining, so that the temperature would be the same as that to which the tape was exposed. The tape was pulled up to a strain of 15 lb. and held there until the rear chainman, who was centering the end mark over the tack, called "all right". The pin was then stuck, the tape eased off and then pulled up again, and the position of the pin checked. The head chainman then entered the chain length and the temperature in his book. When the next hub was reached, a pin was set at the last full meter, and the meters were read. Then the two chainmen changed places, and the plus was read again. The fractional meter was read by a piece of Chesterman steel tape, the number of entries in the book were verified by counting the pins, these were again bunched, and a new course was started.

The notes read as follows:

219	100	82°	311.624
to	100	83°	+.04259
220	100	83°	311.66659
	11.624	83°	

The work at the right of the foregoing was done by the transitman, and was the reduction to 62°, with a coefficient of 0.0000065 per degree. This reduction was here plus, and for 83° — 62° = 21 degrees. The tape was standard at 62 degrees.

A run ahead was made for half a day. Then the forward chaining book was given to the transitman, and the backward one obtained; then the measurements were made again, but in the opposite direction. The notes for the foregoing course then read:

220	100	88°	311.620
to	100	88°	+.05273
219	100	88°	311.67273
	11.620	88°	

The correction for temperature in this case was for 26 degrees. The mean of the two measurements was 311.66966, and the difference between the two was 0.00614. As the allowable difference was 0.016 (5 mm. per 100 m.), the chaining checked, and the adopted distance was: A-219 to A-220 . . . 311.67.

It is not assumed that chaining can be done to five decimals, but they were used simply for convenience in computing the correction for temperature. The chaining was actually done to millimeters, but the adopted distances were only carried to centimeters. The writer does not approve of recording the results of any work in figures which indicate an accuracy beyond that which the actual working conditions will give.

This chaining approximates quite closely in accuracy to that done in measuring secondary bases, where it is customary to use some mechanical arrangement, such as a lever, to hold the end of the chain firmly and perfectly still. Better work should result from such an appliance, but its use consumes time. It appeared that results sufficiently accurate could be obtained without it, and so none was used.

Elongation of Polaris.—The elongation of Polaris was usually taken at each camp, these being from 6 to 8 miles apart. The azimuths of the stadia lines were checked on these elongations and also that of the precise line, if the latter were near enough. As the camp was always on the river, in houseboats handled by a gasoline launch, it sometimes happened that it was a mile or two from the precise line. In that case, an elongation was taken from an "A" hub, or the azimuth of the precise line was not checked until the next camp was reached.

When an elongation was to be taken, a point for the hub was chosen and a line about 100 m. long was cleared along the proper

azimuth. Some 15 or 20 min. before the computed time, the transit was carefully set and leveled, pointed to the polar star, and clamped. The star was followed until it was seen that it had nearly reached its elongation. Then a hub was driven, and a chaining pin (with a sheet of white paper back of it and a light back of that) was held on the hub. The cross-wires of the transit were illuminated by the light of a candle in a tin can directed on a piece of white paper with a hole in the center, which was fastened by a rubber band on the shade of the object glass. The transit was again turned to the star and kept there until the latter was seen to drop (or rise) along the wire. Then line for tack was given, on the pin; the transit was reversed and set again on the star and another point set on the hub, and the tack was put half way between the two. For the whole time of the survey the bearing of the elongation was assumed to be 1° 18′ (azimuth, 358° 42′ for western elongation and 1° 18′ for eastern).

In the writer's opinion, more accurate results can be obtained in this way than in observing Polaris at any time, referring it to some hub previously set by reading the plates, and then computing the azimuth of the line from the transit to the hub. The two principal objections to this latter method are, the uncertainty which may exist as to the exact time of the observations and, more important still, the use of a light around the transit for reading the verniers. Where there is light there is heat, and the heat expands one side of the transit, thus affecting the verniers. Both methods have been tried, with the invariable result that the observation of the elongation was the more accurate.

Measuring Angles.

The transitman worked ahead of or behind the chainmen, whichever was more convenient. He had two flagmen, each equipped with an 8-ft. transit rod having three guy wires on it, and a plumb-bob. The rod was set up on a hub, guyed to the stakes before mentioned, and plumbed. It was found that, with his hands, a man could not hold a rod so firmly that the angles read to it would check within the desired limit.

Starting at a hub from which the elongation of Polaris had been observed, the transitman set his left-hand or "A" vernier to read zero, and read the right or "B" for seconds, recording both readings. He then noted on which side of the traverse line was the angle which

was less than 180°, and set his instrument on the left-hand stake, clamped the plate, and turned to the right-hand stake; he then read and recorded vernier "A", simply as a check on the later work. Unclamping the lower plate, he turned to the left-hand point and accumulated the angle twice more on the plate; then he reversed the telescope and accumulated the angle three times more, read and recorded both verniers, observed whether his line of sight was still pointing to the right-hand rod, and, if not, set it back with the lower slow-motion screw, swept the outside angle three times, erected the telescope, and swept it three times more, ending with the instrument pointing to the left-hand hub. He then carefully read and recorded both verniers. If there had been no slip in the instrument and his pointings had been perfect, his verniers would read the same at the close as at the beginning.

The following shows the notes of the angle at A-219:

Left-Hand Page.

Instrument.	A.	B.	Mean.
Inst. at A-219	00′ 00″	00′ 00″	
∆ A-218–A-220	124° 16′ 40″		
	25° 39′ 30″	39′ 30″	
	00′ 20″	00′ 20″	

Needle N. 86° 05′ E.

Right-Hand Page.

	25° 39′ 30″	124° 16′ 35″	124° 16′ 33.4″
	334° 20′ 50″	55° 43′ 28.3″	55° 43′ 26.6″
		180° 00′ 03.3″	
Az. 219-220		85° 58′ 23.5″	

The entry, ∆ 218-220, shows that 218 was first sighted to, and that the deflection at 219 was to the north, that is, 218 is the left-hand point, and the transit swings to the north and east in reaching 220.

The 124° 16′ 40″ is the first reading of the angle.

At the end of the six accumulations, the verniers both read 25° 39′ 30″, and at the close they both read 00′ 20″. If they had read differently —as 00′ 00″ and 00′ 10″—at the start or any other place, then another column of mean readings would have shown, as, for the foregoing, 00′ 05″. The notes to this point are recorded on the left-hand page of

the notebook and comprise the record of the field work. The rest are on the right-hand page, and constitute the reduction.

As the verniers both read 00 at the start, the 25° 39′ 30″ is carried across as the true reading of the summation of the six repetitions of the angle. Subtracting this from 360° 00′ 20″ gives 334° 20′ 50″ as the true accumulation of the exterior angle. Dividing each by 6, and adding to the first the necessary full revolutions of 360° (in this case 2) in order to give the proper angle 124°, there results the two angles given. The last one is really 180° less than was measured, but, for purposes of reduction, it is the deflection angle which is wanted, which is the above amount (180°) less than the exterior angle. The sum of these two measured angles is 03.3″ in excess of 180°, and shows the instrumental slip or error in pointing. This is divided equally between the two angles, and the deflection angle at 219 is thus determined to be, 55° 43′ 26.6″ to the left, or north.

The computed azimuth from 218 to 219 was 141° 41′ 50.1″, so that, subtracting the deflection at 219 from this, the azimuth, 219-220, is 85° 58′ 23.5″.

This azimuth is not corrected for easting nor for instrumental error. The former depends on the distance from A-204, where the last elongation was taken, and the latter was found to be, at A-222, where the next star hub was set, 24.9″ too large in 19 angles, or 01.3″ per angle. The final true azimuth of this course was found to be 86° 00′ 04″.

Each night the notes of angles measured during the day, together with the distances, were given to the computer, who calculated the eastings and thus corrected the azimuths and made up a table of preliminary locations from R. P. "E" of all points, so that they could be platted on the map. When the run was tied through to Polaris, and the azimuths were corrected for instrumental error, the final latitudes and departures were computed. The preliminary figures were never in error as much as 1 m., or, they were as close as they could be platted. Of course, they were corrected and started right whenever an elongation was taken.

Accuracy of Angular Work.—Table 1 gives the whole line from Roma to the Gulf, and shows the corrections used. The run from A-144 to A-180 was rejected, and the azimuths of the Mexican Section were used, but it is included here to show the actual results of

the season's work. The total number of angles exceeds the courses given for the A line, because several elongations were taken on spur lines to reference points, and these angles were counted in making the correction as well as the angle to each star. Elongations were taken from the points given in Columns 1 and 2.

TABLE 1.—INSTRUMENTAL ERRORS IN PRECISE LINE.

(1) Star.	(2) To star.	(3) Closing error.	(4) Number of angles.	(5) Error per angle.	(6) Remarks.
Z-399	Z-408	+ 00′ 14.7″	11	01.5″	
Z-408	A-1	+ 01′ 07.1″	31	02.1″	
A-1	R.P-3	− 00′ 14.0″	13	01.0″	
R.P-3	R.P-7	+ 00′ 38.0″	19	02.0″	
R.P-7	A-58	+ 00′ 21.0″	12	01.8″	
A-58	R.P-12	− 00′ 39.9″	24	01.7″	
A-78	R.P-16	+ 00′ 54.0″	32	01.7″	
R.P-16	R.P-18	+ 00′ 38.2″	19	02.0″	
R.P-18	A-144	+ 00′ 50.3″	25	02.0″	
A-144	A-180	+ 01′ 47.7″	37	02.9″	Rejected.
A-180	A-204	− 00′ 05.7″	26	00.2″	
A-204	A-222	+ 00′ 24.9″	19	01.3″	
A-222	A-246	+ 00′ 11.9″	25	00.5″	
A-246	A-260	+ 00′ 00.4″	15	......	
A-260	A-281	− 00′ 36.1″	22	01.6″	
A-281	A-300	+ 00′ 38.0″	20	01.9″	
A-300	R.P-48	+ 01′ 02.9″	37	01.7″	
A-334	A-374	+ 01′ 10.0″	41	01.7″	
A-374	A-382	− 00′ 18.0″	11	01.6″	
		11′ 52.8″	439	01.62″	
	Rejecting A-144 to A-180				
		10′ 05.1″	402	01.51″	

Table 1 shows that the average instrumental error, in turning 439 angles, was 01.62″ per angle, or, rejecting the run from A-144 to A-180, the average was 01.51″ per angle for 402 angles. This does not mean that, with a 6-in. plate, reading to 20″, each angle can be read with certainty to this degree of accuracy, but that the average error can be, and was, brought down to this small amount. It requires great care in handling the instrument and great care in pointing. The weather conditions also affect the work, but the latter was continued in heat and in wind just as long as the rod could be seen or a man could stand at the instrument. The orders were to keep up with the outfit, and every man was trying to make the others do the keeping up.

The signs in Column 3 of Table 1 show the transitman's personal equation. He nearly always had too large an azimuth. Whenever he failed to close within the limit, his azimuth was invariably too large.

The writer does not know that any precise line work similar to this has been done elsewhere. Triangulation has generally been used for the exact location of points. With an expert instrumentman, the limit of 2″ per angle is permissible, but it is extremely difficult for an ordinary man, however careful he may be, to keep within this limit, and it would be advisable to raise it to 3″. In the spring of 1913, the writer had 60 miles of similar work done in the El Paso Valley of the Rio Grande. The same transit was used, but with another man handling it, who was allowed 4″ per angle for instrumental error. His average error on 234 angles divided into 8 runs was 1.85″. His best run showed a closure of 1.13″ per angle for 37 angles and his worst, 3.20″ per angle for 24 angles.

Table 2 gives the sum of the forward chaining distances (from hub to hub) between star points, the sum of the backward chainings, the sums of the differences between adjacent hubs and their arithmetical sums, and the ratio of error deduced from these, as well as the algebraic sums of errors and the resulting ratios, and the algebraic sum of the total errors with its ratio.

Table 2 shows that the line was broken up into nineteen runs with lengths varying from 5 600 to 22 700 m., and averaging 12 600 m.; it also shows that the number of courses into which each run was broken by angle points varies from 10 to 37, the total being 411. When the forward chaining between adjacent hubs was larger than the backward, the difference was called plus, and the reverse was called minus. These were summated and entered in Table 2 as sum of differences, plus, minus, and total, the latter being the arithmetic sum of the plus and minus sums. The ratio of error was found by dividing the distance by the total differences. These ratios run from 1 in 44 000 to 1 in 184 000, and the average for the whole line is 1 in 91 000. Not a single course was omitted, although in checking the work in the office, one was found which exceeded the allowed limit of 1 in 20 000. It was from A-180 to A-181, the distance being 752 m. and the difference, 0.068 m., or 1 in 11 000. All

TABLE 2.—ERRORS IN MEASURING PRECISE LINE.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Station.	To station.	Number of courses.	Forward.	Backward.	Sum of Differences.			Ratio: 1 in	Net Difference.		Ratio: 1 in
					+	−	Total.		+	−	
R.P-" E "	Z-408	10	5 623.401	5 623.504	0.013	0.116	0.129	44 000		0.103	55 000
Z-408	A-1	28	12 926.099	12 926.143	0.089	0.133	0.222	58 000		0.044	294 000
A-1	R.P-3	12	6 947.551	6 947.594	0.022	0.065	0.087	80 000		0.043	162 000
R.P-3	R.P-7	18	11 123.838	11 123.877	0.023	0.062	0.085	131 000		0.039	285 000
R.P-7	A-58	11	8 968.783	8 968.754	0.058	0.029	0.087	103 000	0.029		309 000
A-58	A-78	21	9 199.590	9 199.549	0.061	0.020	0.081	114 000	0.041		224 000
A-78	R.P-16	29	18 524.327	18 524.411	0.056	0.140	0.196	94 000		0.084	221 000
R.P-16	A-121	17	9 871.010	9 870.988	0.043	0.021	0.064	154 000	0.022		449 000
A-121	A-144	23	12 952.137	12 952.231	0.020	0.114	0.134	97 000		0.094	138 000
A-144	A-180	36	20 442.481	20 442.551	0.116	0.186	0.302	68 000		0.070	292 000
A-180	A-204	25	14 102.703	14 102.665	0.124	0.106	0.230	61 000	0.018		783 000
A-204	A-222	18	11 264.993	11 265.187	0.023	0.217	0.240	47 000		0.194	58 000
A-222	A-246	24	11 924.062	11 924.081	0.034	0.053	0.087	137 000		0.019	627 000
A-246	A-260	14	8 063.971	8 064.029	0.010	0.068	0.078	103 000		0.058	139 000
A-260	A-281	21	11 679.774	11 679.791	0.048	0.065	0.113	103 000		0.017	687 000
A-281	A-300	19	11 037.223	11 037.221	0.031	0.029	0.060	184 000	0.002		
A-300	A-334	34	19 760.327	19 760.415	0.035	0.123	0.158	125 000		0.088	225 000
A-334	A-374	37	22 727.641	22 727.605	0.085	0.049	0.134	170 000	0.036		631 000
A-374	R.P-55	14	12 219.289	12 219.270	0.073	0.054	0.127	96 000	0.019		643 000
		411	239 359.180	239 359.866	0.964	1.650	2.614	91 000	0.167	0.853	
									Net ...	0.686	349 000

other measurements checked within the limit. This ratio of 1 in 91 000 is an actual ratio without any chance for compensating errors, except such as may occur between the individual chain lengths. Each distance between hubs formed a run by itself, and its error of closure is counted.

As a matter of curiosity, there is shown in Table 2 the algebraic sums of the differences of each run, with the resulting ratios and the final algebraic sum (0.686 m. in 239 km.), with its ratio of 1 in 349 000. This is the total net difference between the forward and backward measurements. As the mean is half way between, either line varies only 34 cm. from the mean for the whole distance from Roma to the Gulf. This, however, is interesting only as showing how errors in work carefully done are likely to balance. The true difference between the two measurements is 1 in 91 000, or the variation of either from the mean is 1 in 182 000.

It should be understood that this chaining was done in the regular day's work, with no arrangement for holding the tape still over the tack, as is usually done. Chaining pins were used, instead of hubs with plates and hair lines, as is sometimes the practice.

Rate of Progress.

Between the beginning and end of the survey about 110 working days intervened. Several banco ties were made by the precise line party, probably 10 days being used on that, thus leaving 100 days for precise line work. About one-third of this time was spent by the chainmen in locating line, and several days were also spent in re-chaining distances which did not check within the limit. There remained about 60 days in which a distance of 150 miles was chained twice, or, the rate of chaining was 5 miles per day of from 8 to 9 hours' actual work. The whole work of chaining and recording was done by the two chainmen, with no assistance except, perhaps, an axeman who carried their water canteens, lunch bucket, coats, etc.

As the transitman measured so many of his angles a second, and sometimes a third time, it is hard to give his rate of progress. He probably could measure from 8 to 10 angles in an ordinary day's work. Fifteen angles per day is fast work for an expert.

Primary Levels.

It was desirable to have a moderately accurate line of levels from Roma to the Gulf. There was no occasion for a line of what scientists would call precise levels, run with an instrument of great sensitiveness, shaded from the sun, with three wires to be read, two rods, and rodmen with levels on their rods, etc., etc. It was decided to obtain the best possible results from an engineer's ordinary 18-in. Wye-level and a target rod held on nail heads or round-topped pegs, waved on each reading, and read to millimeters. There was nothing unusual about this level work. The line was run in the ordinary way, that is, a run forward for about a mile was made and checked back. Then the mean height of the point ahead was computed and, using it, another mile was run, etc. The limit of error allowed between benches was

$$0.01 \text{ m. } \sqrt{\text{distance, in miles, between benches.}}$$

Table 3 shows the results of this leveling.

TABLE 3.—Closing Errors in Primary Levels.

(1) From:	(2) To:	(3) Closing error, in meters.	(4) Distance, in miles.	(5) √Distance.	(6) Coefficient.
R.P-"E"......	R.P-2........	—0.006	13.3	3.65	0.0016
" 2	" 7........	—0.006	9.4	3.07	0.0020
" 7	" 13........	+0.009	15.5	3.94	0.0023
" 13	" 18........	—0.022	13.3	3.65	0.0060
" 18	" 22........	—0.030	11.4	3.38	0.0090
" 22	" 28........	+0.009	18.1	4.25	0.0021
" 28	" 34........	—0.011	13.8	3.71	0.0030
" 34	" 39........	—0.031	13.3	3.65	0.0085
" 39	" 45........	+0.007	11.9	3.45	0.0020
" 45	" 50........	—0.043	13.8	3.71	0.0116
" 50	" 55........	—0.016	15.5	3.94	0.0041
Totals......................		—0.140	149.3	12.22	0.0114

Remembering that the allowable coefficient of error is 0.0100, an examination of Column 6 shows that all the separate runs excepting one, were within the required limit, but that the total was a little outside the limit. The net error was —0.140 m., the allowable would have been 0.122, or, the line as a whole exceeded the allowed limit by 18 mm.

It will be noted, however, that other combinations can be made which will show larger errors. Table 4 was compiled to show these,

the quantities being taken from Table 3. Column 6 shows that two runs, namely, from R.P-13 to R.P-22 and from R.P-45 to R.P-55, exceeded the limit, the first by 2 mm. and the second by 5 mm.

TABLE 4.—CLOSING ERRORS IN PRIMARY LEVELS.

(1) From:	(2) To:	(3) Closing error, in meters.	(4) Distance, in miles.	(5) $\sqrt{\text{Distance}}$.	(6) Coefficient.
R.P-"E"......	R.P-7........	−0.012	22.7	4.76	0.0025
" 7	" 13........	+0.009	15.5	3.94	0.0023
" 13	" 22........	−0.052	24.7	4.97	0.0105
" 22	" 28........	+0.009	18.1	4.25	0.0021
" 28	" 39........	−0.042	27.1	5.21	0.0081
" 39	" 45........	+0.007	11.9	3.45	0.0020
" 45	" 55........	−0.059	29.3	5.41	0.0109

Table 5 shows the line broken into four approximately equal parts, and all except the last, which is from R.P-45 to R.P-55, are within the limit.

TABLE 5.

(1) From:	(2) To:	(3) Closing error, in meters.	(4) Distance, in miles.	(5) $\sqrt{\text{Distance}}$.	(6) Coefficient.
R.P.-"E".....	R.P.-13........	−0.003	38.2	6.18	0.0005
" 13	" 28........	−0.043	42.8	6.54	0.0066
" 28	" 45........	−0.035	39.0	6.24	0.0056
" 45	" 55........	−0.059	29.3	5.41	0.0109

It is hardly fair to this work to compare it with precise level work, because the latter is done with so much greater care. The following comparison, however, is given.

Johnson's "Surveying" gives the following limits of error—all in meters and kilometers. The equivalent of

0.01 m. $\sqrt{\text{distance in miles}}$ is 0.008 m. $\sqrt{\text{distance in kilometers}}$.

U. S. Coast and Geodetic Survey... $0.004\sqrt{K}$
U. S. Lake Survey................ $0.010\sqrt{K}$
Mississippi River Survey........... $0.005\sqrt{K}$ or $0.003\sqrt{2K}$

It will be seen that this line of levels meets the requirements of the Lake Survey, but not those of the other two. Although the difference between a coefficient of 8 mm. and one of 4 or 5 mm. is small, the indicated precision is much greater with the smaller coefficients, and necessitates a finer instrument and more delicate manipulation.

In a paper entitled "Surveying,"* by Officers of the United States Geological Survey, it is stated that when duplicate precise lines are run, as in the case under consideration, the error allowed by the U. S. Geological Survey is 0.02 ft. $\sqrt{2D \text{ in miles}}$. This coefficient equals 0.007 m.

In Table 6 this is applied to the three worst runs, namely, R.P-13-22, R.P-45-55 and R.P-"E"-55.

TABLE 6.—COMPARISON IN PRIMARY LEVELS.

(1) From:	(2) To:	(3) Closing error, in meters.	(4) Twice the distance.	(5) $\sqrt{2D}$	(6) Coefficient.
R.P-13..........	R.P-22.......	—0.052	49.4	7.03	0.0074
" 45..........	" 55.......	—0.059	58.6	7.65	0.0077
" "E".......	" 55.......	—0.140	298.6	17.28	0.0081

Table 6 shows that the work nearly met the requirements of the Geological Survey for precise levels, run with high-grade instruments, umbrellas, etc.

Rate of Progress.—Including spur lines to reference points away from the precise line, the primary levels covered a double run of about 155 miles, or 310 miles of single line. The leveler worked half the time on this line and half the time on the river. Two or three days were used in going back to check out an error, etc., so that, there having been 110 working days during the survey, 51 or 52 days were devoted to the primary leveling. The rate of progress is seen to have been 6 miles of single line per day.

STADIA LINES.

Thesis.—It is the writer's belief that too many refinements are usually applied to stadia work, and that they give to it a factitious value without adding anything to the accuracy of the results. Thus, rod levels are used to keep the rods plumb; the stadia interval is determined with great nicety for each instrument and each observer; a rating table is made up which involves $f + c$ and is usually carried to centimeters; stadia readings are reduced by this table, thus running all distances into centimeters and giving to the work an appearance of accuracy which does not exist.

* *Transactions*, Am. Soc. C. E., Vol. LIV, Part B, p. 426.

Believing that these refinements are a waste of time, with no corresponding valuable result, but that steady, careful instrument work, disregarding $f + c$, and, in case the stadia interval checks out close to unity on a measured base, using stadia readings direct, without reduction tables, would give just as good results, all the stadia work on this survey was done in this way. The following discussion shows the results.

The principal part of the survey work was the taking of topography by stadia. Three parties were on this portion of the survey from start to finish. One was charged with the river and as much of the adjoining country as could be reached conveniently. The second devoted its time to the Texas side of the river and the third to the Mexican side. The work was platted on the map as soon as possible after being taken, so that running track was kept of the areas not covered. They were examined, and, if anything of importance was found, a line was run to it. About 375 sq. miles of country were covered by the three parties. Altogether, 37 000 shots were taken, locating, by azimuth, distance, and elevation, that many points on the ground. In addition to these, some 9 000 shots were taken in former surveys of bancos, which were platted on the map, so that 46 000 points were located by stadia, or an average of 123 shots (including transit points) per sq. mile. There were 4 900 hubs set, or 13 per sq. mile.

Each stadia party consisted of a topographer, who handled the transit, recorded the notes, and made his sketches; an American rodman who usually kept ahead, choosing places for transit points, and keeping an eye on the stadia men; a rear flagman, two or three stadia men, and as many axemen as were needed. On the river line, a skiffman was also used. The native labor of the country was used for flag, stadia and axemen. Few could speak English, although many of them were born in the United States, as had been their ancestors for generations.

The instruments consisted of a transit and three or four stadia rods. No. 2 transits were used, one reading to 20″ and two to 30″. All had fixed stadia wires which were set by the makers to subtend 1 m. in a distance of 100 m. Careful tests on base lines measured with a steel tape, showed that the setting of the wires was practically

exact. The writer considers adjustable stadia wires a "delusion and a snare," and would not use them under any circumstances.

The stadia rods were of white or sugar pine, with an iron shoe on the bottom, and were of the following dimensions: 4.55 m. (14 ft. 11 in.) long; bottom, 9 by 2.5 cm. ($3\frac{1}{2}$ by 1 in.); and top 7.3 by 1.6 cm. ($2\frac{7}{8}$ by $\frac{5}{8}$ in.). They were graduated and painted as shown by Fig. 1. The figures were 4 cm. high and were centered over the decimeter marks. Notches were painted to mark the decimeter at the ones and sevens. Red was used to mark the full meters and one-half of the diamond at the half meters was also red. As the latter color might become indistinguishable from black at long distances, when the light was bad, the form of the diamond was varied at the meter and half-meter, so that they might be located by their shape. In ordinary weather and light these rods could be read with certainty to centimeters at a distance of from 200 to 300 m. Beyond that distance the readings were uncertain.

As it was formerly the rule to graduate stadia rods to fit each instrument, it should be noted that these rods were graduated to meters and were interchangeable between the different parties.

The face of this rod was so badly exposed that the figures wore off quickly, and it was also limber and hard to keep from warping. It would be greatly improved by screwing to the edges $\frac{1}{4}$-in. strips of hard wood which would project $\frac{1}{8}$ in. beyond the face.

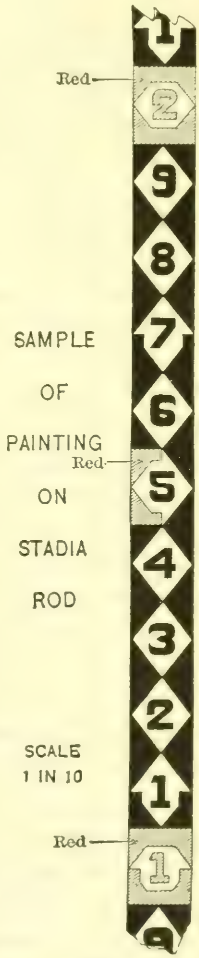

FIG. 1.

Programme of Work.—Starting from a point, the location of which was known and where an accurate azimuth could be had, that is, from "A" or "B" hubs, or from banco corners, or, for want of something better, from stadia hubs in a closed traverse, the topographer ran a traverse which closed on another fixed point or on a point in another stadia traverse

which had been closed. Azimuths were read from 0 at the north around to the right, 90° for east, 180° for south, 270° for west, and 360° or 0 for north again. The programme was as follows:

The topographer set up his instrument over the point, read and recorded the height of the axis of the telescope above the top of the hub, computed the back azimuth of the point he wished to back-sight on by adding 180° to its forward azimuth, which had been read to the limit of the instrument, set his A vernier to read this azimuth, and back-sighted, with his telescope erect, on the edge of a stadia rod which was being centered as nearly as possible over the tack in the back hub. He then signaled to the rear flagman, who turned the face of the rod to the instrument. The topographer then read and recorded the level reading to the back-sight, and the distance, unclamped his plate, and was ready to take topography. The river man started with 0 for his first hub, and gave each shot a consecutive number. He usually had three stadia rods, sometimes four, working, and kept them all going. When a rod came up he turned his instrument on it, read the level (the telescope was kept level all the time if possible), turned the micrometer screw until the lower wire caught a full meter mark, read the upper wire, mentally deducting the reading of the lower wire, turned the micrometer back until the middle wire read the level reading, so that the telescope was again level, entered in his book the level and stadia readings, waved the stadia man all right, which released him, and then read and recorded his azimuth. The level reading was taken to centimeters, the stadia to centimeters, and the azimuth to the nearest 10′, except on very long sights, when it was read to 5′. For convenience in platting, one side of the river was given from six to eight consecutive numbers, and then the other side the same, but the readings were taken whenever a rod came up.

When the readings were all taken as far as the transitman could see, the rodman located a hub and put a tack in it, signaling for "point". The topographer set his vernier back to the back azimuth, noted whether or not the transit had settled, re-leveled if it had, and sighted to the back rod, which, as before, was being held over the tack, and then, turning ahead, read and recorded the azimuth to the new hub. The head rodman then turned his rod, and the level and stadia were read, and recorded. In this way levels and distances

were read twice on all turning points—once forward and once backward.

The stadia was read direct, that is, the lower wire was placed, if possible, on an even meter mark, and the intercept between it and the upper wire was read. Sometimes it is specified that, on turning points, the lower, middle, and upper wires shall be read and recorded, and then the intercept computed. It is claimed that this eliminates the danger of errors. This is quite true, but it also eliminates time to such an extent that it retards the progress of the party.

PAGE OF RIVER BOOK.

From:	To:	Azimuth.	Corrected Az	Stadia.	H. I. Rod.	Elev.
	Etc.	Etc.				
4 406 ⊙	4 393 ⊙	238° 30′ 30″	....	2.29	22.09 2.79	20.69
	4 406 ⊙	58° 30′ 30″	58° 27′ 30″	2.29	0.15	(1.40)
	Cor. 2 ⊙	54° 37′	....	1.985	H. I. + 0° 29′	20.0
	5	98° 10′	....	1.75	0.80	20.0
	4	52° 20′	....	1.65	1.00	19.8
	3	115° 10′	....	1.28	0.60	20.2
	2	64° 40′	....	2.30	H. I. — 0° 59′	15.3
	1	76° 20′	....	1.00	H. I. — 2° 18′	15.3
	4 400	54° 50′	....	1.12	1.00	19.8
	99	170° 00′	....	2.40	1.10	19.7
	98	41° 50′	....	1.18	0.80	20.0
	97	155° 10′	....	0.35	H. I — 6° 54′	15.1
	96	154° 50′	....	1.17	0.60	20.2
	95	340° 00′	....	0.40	2.80	18.0
	94	340° 10′	....	0.18	4.00 + 2° 20′	20.0
4 393 ⊙	4 382 ⊙	236° 39′	....	3.75	20.80 0.62	19.28
	4 393 ⊙	56° 39′	56° 36′	3.75	2.45	(1.52)

(From River Book No. 10, page 19.)

When the above record was made, the topographer went ahead to the new point, made his sketch, set up, and repeated the operations.

The notes were kept in books especially made for this work, with wider pages than usual. The notes ran up the page. On the previous page there is a sample of the notes on the left-hand page of a book. On the right hand were made the sketches and such entries, in the form of remarks, as were deemed necessary. The shot numbers, being between 0 and 5 000, show that this was on the river.

The notes on the right-hand page showed that the "Cor. 2" tied to was Cor. No. 2 of La Palma Banco No. 25. It happened that at this point the azimuths were, for some reason, being corrected — 03′. The elevations underscored thus, 19.28, were those of the hubs, and were obtained by the leveler. The entries in the elevation column enclosed in circles were the height of the telescope above the hub, and the entries in the sixth column were the height of instrument above datum. Of course, the notes and sketch on the right-hand page showed where all these readings were taken. This was an ordinary set-up for the river, as regards number of shots, but, on the side lines, fewer shots were taken from each hub, and sometimes brush had to be cut for each shot, so that progress was slow.

Every night the stadia hubs set during the day were platted on the map, and if a line ran to a closure and closed within a reasonable limit, the line was adjusted graphically. The error allowed depended on the length of the traverse, but roughly, was about 2 m. per km. If the error was more than that, the line was usually re-run in the field. If an error of azimuth of more than 5′ developed in the field on closure, the line was re-run. Probably a dozen re-runnings were made during the winter's work, which shows that the topographers were careful with their work.

Use and Abuse of Stadia.—The use of stadia in taking topography has come into vogue in comparatively recent years. It was used extensively on the re-survey of the United States-Mexico boundary west of El Paso, in 1892 and 1893. All the topography which the present Boundary Commission has taken has been with the stadia. It was formerly the custom to use rod levels on the rods, to determine and frequently to check a "stadia interval" for each instrument and each man, to take into account the focal distance plus the distance of the object glass from the axis of the telescope ($f + c$), which, in the small transits used on this survey, is about 30 cm. and to compute distances from a stadia reduction table made for each instrument, and frequently car-

ried to centimeters. Such tables were used by this Commission on the 1897-98 re-survey of the lower river.

As the nearest that the stadia interval can usually be read, at distances of about 200 m. or more, is to the centimeter, which means a meter in distance, it has always seemed to the writer that too great refinements had been attempted. It purported to give to stadia work a degree of accuracy which did not exist, and thus added to its cost without any real gain, as well as giving it a factitious value. All these refinements use up time; the purpose of taking topography is usually to get all one can in the shortest possible time, and to have it so accurate that errors would not be noticeable on the map—in this case 1 in 5 000—which is to be made.

On this work, each man checked his stadia interval on a chained base at the beginning and ending of the work, and one topographer, who seemed to get his distances too short, checked his several times. No material variation from the ratio of 1 in 100 between stadia intercept and distance could be detected. Therefore, the reduction tables were dispensed with, as well as rod levels, and the topographer read his rod as far as he could see it, regardless of whether or not the lower wire cut the rod near the ground. Work was not stopped on account of the "boiling" of the air caused by heat, nor on account of wind, as long as a man could hold a rod. The following analysis of the results will show whether or not it was wise to dispense with these refinements. Of course, if the stadia wires of an instrument do not intercept 1 m. at 100 m., a stadia reduction table must, perforce, be used until the instrument can be sent to the makers and adjusted. The stadia wires should always be "fixed", not "adjustable".

Within its proper sphere, the stadia is unsurpassed in the taking of topography. In any work where a variation of 1 or 2 m. in the relative location of points near together, or 5 or 6 m. in that of those which are material distances apart, can be tolerated, the stadia offers a most rapid and handy method of work; but, where exact, or nearly exact, location of points must be had, as in the better class of land surveys and in all town and city surveys, it is too inaccurate for satisfactory use.

Accuracy of Stadia Work.—After leaving the field, it was decided to compute and balance all the stadia traverses. This gave an opportunity to determine the accuracy of the stadia work. The work

naturally divided itself into three parts, the river line, the Texas topography, and the Mexican topography, but various considerations induced a division of the work into four parts, as follows:

First. All the river work except six traverses: This was all done by an expert instrumentman, with former experience in stadia work. The sights were usually open ones, many being across the water. The distances between hubs were fairly uniform, and were long, as were the traverses, so that errors would compensate. The best results should be expected from this work.

Second. All the Texas traverses, together with two river traverses which were run by the Texas topographer: He was a good instrumentman, without previous experience with stadia; he was working in brush, where he had many bad sights and short distances, and many of his traverses were short. His work could not be expected to show as good results as did that on the river.

Third. The Mexican lines down to San Miguel, about 35 miles below Roma, together with two river traverses near Roma: All traverses were run by green men, and were in brush. All the Mexico lines started from and closed on the river line, so that some discrepancy of closure may be chargeable to it.

Fourth. All the Mexico traverses below San Miguel, together with two river traverses near the Gulf which were run by the Mexico topographer: He was a fairly good instrumentman (with eyes which were slightly defective), without former experience in stadia, and was working the greater part of the time in brush, where sights were likely to be poor and short. Some of the traverses were long, and thus gave a chance for the compensating of errors. Many started from, or closed on, the river line, thus including its error.

TABLE 7.—ERRORS OF CLOSURE AND OF AZIMUTH.

(1) Section.	(2) Number of lines.	(3) Total length.	(4) Number of courses.	(5) Mean length.	(6) Linear error of closure.	(7) Ratio: 1 in	(8) Azimuth error.	(9) Error per angle.
River....	53	395 160	1 140	347	245.2	1 611	70′ 30″	3.7″ (1 140)
Texas....	75	312 721	1 246	251	396.7	788	120′ 12″	7.0″ (1 040)
Upper Mexico.	15	104 742	521	201	130.5	803	13′ 55″	2.3″ (365)
Lower Mexico.	43	238 490	892	267	400.2	596	59′ 45″	4.2″ (847)
Total...	186	1 051 113	3 799	277	1 172.6	896	264′ 22″	4.7″ (3 392)

Although several lines showed evidence of blunders, probably of 10 m. each, in stadia readings, they will all be included in the first analysis, and then they will be dropped and the remaining work analyzed.

Table 7 includes all the stadia lines which were run to a closure.

Some of the lines in Table 7 were run to a distance tie, but not to an azimuth closure. They were as follows:

River section.............	None.	
Texas section............	14 lines	206 courses.
Upper Mexico section....	5 "	156 "
Lower Mexico section.....	2 "	45 "
Total................	21 lines	407 courses.

The azimuth errors in Column 9 are calculated with these courses deducted from the totals. The figures in Table 7 in parentheses show the number of courses used in getting the angular error. This table also shows that there were run and computed 186 lines, aggregating 1 051 km. (653 miles) in length, that the average error of closure was, practically, 1 in 900, and the average error of angle reading, where angular closure was had, was less than 5″ per angle.

One river line, one Texas line, and seven Mexico lines indicated "busts" in stadia readings. They are dropped, and Table 8 is made up without them. It gives a fairer idea than Table 7 of the real accuracy of the work. As the mistakes in stadia readings did not affect the azimuth errors, the latter are not repeated in Table 8.

TABLE 8.—ERRORS OF CLOSURE—OMITTING NINE BAD LINES.

(1) Section.	(2) Number of traverses.	(3) Total length.	(4) Number of courses.	(5) Mean length.	(6) Linear error of closure.	(7) Ratio: 1 in
River................	52	383 596	1 112	345	228.0	1 682
Texas................	74	304 733	1 226	249	377.8	807
Upper Mexico.......	13	87 822	446	197	97.0	905
Lower Mexico.......	38	202 632	768	264	285.8	709
Totals.........	177	978 783	3 552	276	988.6	990

Table 8 shows that 177 lines, presumably free from "busts", aggregated 979 km. (or 608 miles) in length, and that the average error of closure was a little greater than 1 in 1 000.

Table 9 gives the notes of the nine lines which were omitted from Table 8. It should be understood that these lines were not rejected because their ratio error showed so large, but because the absolute failure to close was so great. Several shorter lines showing larger ratios of error than these, have been left in Table 8.

TABLE 9.—REJECTED LINES.

(1) Section.	(2) From:	(3) To:	(4) Length.	(5) Courses.	(6) Mean length.	(7) Errors of Closure: Lat.	(8) Dep.	(9) Linear.	(10) Ratio: 1 in
River.......	B-279...	R-3 681.	11 564	28	413	15.11 S.	8.29 E.	17.23	671
Texas.......	R-619...	R-817...	7 988	20	399	7.37 S.	17.39 E.	18.88	423
Up. Mex...	Z-399...	Z-408 ..	8 782	33	266	9.23 S.	14.19 E.	16.92	519
" " ...	R-00....	R-237...	8 138	42	194	4.67 S.	15.89 W.	16.56	497
Low. Mex..	M-8 151	M-8 336	5 426	20	271	16.91 N.	11.88 W.	20.66	262
" " ..	R-1 997.	R-2 340.	6 601	35	189	2.33 S.	18.56 W.	18.70	254
" " ..	M-9 647	R-96....	6 954	19	366	6.31 S.	17.44 W.	18.55	375
" " ..	R-114...	R-517...	7 686	23	334	21.14 S.	15.51 W.	26.20	293
" " ..	M-7 555	R-1 052.	9 191	27	340	8.95 N.	29.00 E.	30.35	303
		9 lines	72 330	247				184.05	393

Mean length, 8 037

Table 9 shows that nine lines, aggregating 72 km. (45 miles) in length, have been rejected, because it was apparent that there were one or more mistakes in stadia reading in each. It also shows that their average ratio of error is a little greater than 1 in 400.

In order to determine, if possible, whether or not the different topographers were systematically reading distances short or long, Table 10 was made up. It is assumed that each section had but one series of lines, the general course and total net length of which were as shown in Column 6, which is made up from Columns 4 and 5. The quantities in Columns 4 and 5 were scaled from the map. The sums of the errors of latitude, both north and south, and their net sums, with the proper signs, are given in Columns 7, 8, and 9; the same for departure are given in Columns 10, 11, and 12. Column 13 gives the net linear error of closure, and Column 14 gives the ratio.

Table 10 indicates that the river topographer slightly over-ran on distances, as a general thing; that the Texas topographer balanced remarkably well; but that the Mexico man under-ran quite badly. This confirms the belief that he was inclined to read the stadia too short.

In some places there were two or more side lines parallel to each other, so that the assumption that there was only one series of lines is not exact. There were other disturbing elements which make the results in this table doubtful. It has no especial significance, except that it shows, in a way, the personal equations of the men.

TABLE 10.—General Closure of Lines.

(1) Section.	(2) From:	(3) To:	(4) Lat. S.	(5) Dep. E.	(6) Course and distance.
River	10 km. below Roma	9 km. from Gulf	47 000	168 000	S. 74° E. 174 500
Texas	Roma	Gulf	50 000	187 000	S. 75° E. 193 600
Up. Mex	Roma	San Miguel	19 000	43 000	S. 66° E. 47 000
Low. Mex	San Miguel	Gulf	31 000	143 000	S. 78° E. 146 200

(7) Error. N.	(8) Error. S.	(9) Error. Net.	(10) Error. E.	(11) Error. W.	(12) Error. Net.	(13) Net linear.	(14) Ratio: 1 in
64.16	78.88	14.72 S.	120.27	21.81	98.46 E.	S. E. 99.55	1 750
113.14	114.35	1.21 S.	127.78	117.09	10.69 E.	S. E. 10.76	18 000
8.43	27.22	18.79 S.	18.69	52.27	38.58 W.	S. W. 38.48	1 220
133.95	54.40	79.55 N.	22.83	160.46	137.63 W.	N. W. 158.97	920

Tables 11, 12, 13, and 14 show the number and length of the lines in the several sections which had certain ratios of error, and Table 15 shows the same thing for all the 177 accepted lines. These tables also show the poorest and the best ties for each section, and the shortest and longest lines in each section and in the whole.

Table 11 shows that the worst closure on the river was 1 in 408 and the best, 1 in 18 042; that the length of the shortest traverse was 1 889 m. and the longest, 17 897 m., the average being 7 377 m.; that less than 4% of the work was poorer than 1 in 800, that nearly half (48%) was between 1 in 1 000 and 1 in 2 000, and that almost 30% was better than 1 in 3 000. Table 12 shows that the worst closure on the Texas work was 1 in 210 and the best, 1 in 5 542; that the length of the shortest line was 1 329 m. and the longest, 11 320 m., the average

being 4 118 m.; that 3% of the work was poorer than 1 in 400, and that 80% was evenly distributed from 1 in 400 to 1 in 1 500.

Table 13 shows a poorest line of 1 in 285; this was the first traverse of a man without stadia experience. The best line was 1 in 7 596, which was jointly run by two green men. The length of the shortest line was 2 307 m. and the longest, 14 358 m., the average being 6 756 m. Table 13 also shows that 5% was poorer than 1 in 400 and nearly 60% was between 1 in 600 and 1 in 1 000.

TABLE 11.—RATIOS OF ERRORS OF RIVER LINES.

(1) Ratio : 1 in	(2) Number of lines.	(3) Total length.	(4) Shortest.	(5) Longest.	(6) Mean.	(7) Percentage of whole.
400 to 600...	2	5 230	2 426	2 804	2 615	1.4
600 to 800...	2	8 668	1 889	6 779	4 334	2.3
800 to 1 000...	5	29 754	1 965	11 154	5 951	7.7
1 000 to 1 500...	15	115 307	3 349	13 762	7 687	30.0
1 500 to 2 000...	9	69 659	3 336	13 592	7 740	18.2
2 000 to 2 500 ..	4	30 899	3 944	12 670	7 725	8.1
2 500 to 3 000...	1	11 911	.....	......	11 911	3.1
3 000 to 4 000...	8	59 264	4 146	14 678	7 408	15.4
More than 4 000...	6	52 904	5 741	17 897	8 817	13.8
Totals.........	52	383 596	.....	......	7 377	100.0
1 in 408.........	1	2 426	Poorest.			
1 in 18 042.........	1	6 856	Best.			
1 in 780.........	1	1 889	Shortest.			
1 in 8 773.........	1	17 897	Longest.			

TABLE 12.—RATIOS OF ERRORS OF TEXAS LINES.

(1) Ratio : 1 in	(2) Number of lines.	(3) Total length.	(4) Shortest.	(5) Longest.	(6) Mean.	(7) Percentage of whole.
Less than 400....	3	8 939	1 996	3 491	2 980	2.9
400 to 600....	17	58 050	1 329	5 764	3 297	19.1
600 to 800....	18	60 344	1 657	6 756	3 485	19.8
800 to 1 000....	11	62 114	2 475	11 320	5 647	20.4
1 000 to 1 500....	13	64 216	1 550	8 093	4 940	21.1
1 500 to 2 000....	4	15 709	2 959	5 097	3 927	5.2
2 000 to 2 500....	4	18 777	2 827	8 163	4 694	6.2
2 500 to 3 000....	1	5 920	......	......	5 920	1.9
3 000 to 4 000....	2	6 064	2 433	3 631	3 032	2.0
More than 4 000....	1	4 600	......	......	4 600	1.4
Totals.........	74	304 733	......	......	4 118	100.0
1 in 210...........	1	1 996	Poorest.			
1 in 5 542...........	1	4 600	Best.			
1 in 481...........	1	1 329	Shortest.			
1 in 979...........	1	11 320	Longest.			

TABLE 13.—RATIOS OF ERRORS OF UPPER MEXICO LINES.

(1) Ratio: 1 in	(2) Number of lines.	(3) Total length.	(4) Shortest.	(5) Longest.	(6) Mean.	(7) Percentage of whole.
Less than 400...	1	4 325	......	......	4 325	4.9
600 to 800...	4	24 462	2 307	8 184	6 115	27.9
800 to 1 000 ..	3	25 873	4 801	14 358	8 624	29.5
1 000 to 1 500...	1	8 620	......	......	8 620	9.8
1 500 to 2 000...	2	10 645	5 292	5 353	5 322	12.1
3 000 to 4 000...	1	5 845	......	......	5 845	6.6
More than 4 000...	1	8 052	......	......	8 052	9.2
Totals.........	13	87 822	......	......	6 756	100.0
1 in 285...........	1	4 325	Poorest.			
1 in 7 596...........	1	8 052	Best.			
1 in 651...........	1	2 307	Shortest.			
1 in 914...........	1	14 358	Longest.			

TABLE 14.—RATIOS OF ERRORS OF LOWER MEXICO LINES.

(1) Ratio: 1 in	(2) Number of lines.	(3) Total length.	(4) Shortest.	(5) Longest.	(6) Mean.	(7) Percentage of whole.
Less than 400...	5	17 484	2 239	6 806	3 497	8.6
400 to 600...	11	59 418	2 421	8 744	5 402	29.3
600 to 800...	8	42 496	3 048	7 484	5 312	21.0
800 to 1 000...	6	38 833	3 073	10 201	6 472	19.2
1 000 to 1 500 ..	1	5 371	......	......	5 371	2.6
1 500 to 2 000...	3	13 095	2 917	6 449	4 365	6.5
2 000 to 2 500...	1	3 395	......	......	3 395	1.7
2 500 to 3 000...	1	8 540	......	......	8 540	4.2
3 000 to 4 000...	1	7 879	......	......	7 879	3.9
More than 4 000...	1	6 121	......	......	6 121	3.0
Totals.........	38	202 632	......	.....	5 332	100.0
1 in 285..........	1	2 844	Poorest.			
1 in 4 081..........	1	6 121	Best.			
1 in 331..........	1	2 239	Shortest.			
1 in 995..........	1	10 201	Longest.			

Table 14 shows that the poorest line on the Mexico work was 1 in 285 and the best, 1 in 4 081; that the length of the shortest traverse was 2 239 m. and the longest, 10 201 m., the mean being 5 332 m.; that nearly 9% was poorer than 1 in 400, and that 70% was about equally distributed between 1 in 400 and 1 in 1 000.

Table 15 shows that the poorest line was 1 in 210, it having been run in Texas; that the best was 1 in 18 042, it having been run on the river; that the length of the shortest line was 1 329 m., it having

been run in Texas, and the longest, 17 897 m., it having been run on the river; that the average was 5 530 m.; that 3% of the work was poorer than 1 in 400; that 75% was about equally distributed between 1 in 400 and 1 in 2 000, with half of this portion between 1 in 800 and 1 in 1 500, and that 15% was better than 1 in 3 000.

TABLE 15.—RATIOS OF ERRORS OF ALL ACCEPTED STADIA LINES.

(1) Error: 1 in	(2) Number of lines.	(3) Total length.	(4) Shortest.	(5) Longest.	(6) Mean.	(7) Percentage of whole.
Less than 400...	9	30 748	1 996	6 806	3 416	3.1
400 to 600...	30	122 698	1 329	8 744	4 090	12.5
600 to 800...	32	135 970	1 657	8 184	4 249	13.9
800 to 1 000...	25	156 574	1 965	14 358	6 263	16.0
1 000 to 1 500...	30	193 514	1 550	13 762	6 450	19.8
1 500 to 2 000...	18	109 108	2 917	13 952	6 062	11.2
2 000 to 2 500...	9	53 071	2 827	12 670	5 897	5.4
2 500 to 3 000...	3	26 371	5 920	11 911	8 790	2.7
3 000 to 4 000...	12	79 052	2 433	14 687	6 588	8.1
More than 4 000...	9	71 677	4 600	17 897	7 964	7.3
Totals.........	177	978 783	......	......	5 530	100.0
1 in 210.........	1	1 996	Poorest—Texas.			
1 in 18 042.........	1	6 856	Best—River.			
1 in 481.........	1	1 329	Shortest—Texas.			
1 in 8 773.........	1	17 897	Longest—River.			

Table 15 also indicates, in a general way, that the shorter the line, the poorer the closure is likely to be. This is shown more plainly in Table 11, and bears out the statement that the stadia errors, where the work is skilfully done, tend to compensate each other.

Comparison with Other Stadia Work.—Aside from this survey, the most extensive system of stadia lines with which the writer is familiar was that run by the United States Section of the Barlow-Blanco Commission while retracing the International Boundary from El Paso to San Diego in 1892 and 1893.

Major Barlow states* that, in all, 1 692 miles of stadia lines were run. These were of two classes: First, "Main Lines", namely, straight lines run along the tangents or boundary lines, and consequently free from azimuth errors. Second, "Side Lines", namely, ordinary stadia lines in which both angles and distances were determined. Of the first, 675 miles (1 085 km.) were run, of which five sections, aggregating 125 miles, were checked by triangulation, with an average error

* Personal report on this re-survey, by Major Barlow, pp. 156–157.

in distance of 1 in 1 218. Of lines of the second class, 1 017 miles were run, of which 118 lines, aggregating 514 miles (827 km.), or one-half of the whole, were closed on points on the main line, with an average error in distances of 1 in 752. Of these lines 25% showed an error in closing poorer that 1 in 500; in 31% the error was from 1 in 500 to 1 in 1 000; in 30% the error was from 1 in 1 000 to 1 in 2 000, and 14% of the lines were better than 1 in 2 000.

It will be noted that only a portion of these side lines was controlled by triangulation through the main line. How large a portion Major Barlow does not state. The remaining lines simply closed on the stadia "main line" with its probable error of 1 in 1 200. If these 118 lines were distributed uniformly over the whole area, then only $\frac{125}{675}$, or 22 of them, were controlled by triangulation, as those on the Rio Grande were controlled by the precise line either directly, or through another stadia line. Therefore, on account of involving the error of the stadia "main line", the foregoing closing ratio of 1 in 752 is uncertain; it may be larger or it may be smaller than given.

It should be stated that all the river lines started and closed on precise points; that all the Texas lines, except 10 or 12, started and closed in the same way, and these last were controlled by stadia lines which had been adjusted; and that nearly all the Mexico lines tied in to river traverses, which were all controlled. The rule adopted was: first to balance the traverses which closed on precise points, and then, assuming that all points on these were fixed, to balance the lines which ran from them.

Johnson* gives a table (Table 16) showing the particulars of Major Barlow's 118 lines which were run to a closure. Johnson's last column gives the average azimuth error on closing per kilometer of line run. This has been changed to "Azimuth error per angle read", so that the result may be compared with those of Table 7.

Table 16 shows that the approximate length of the 118 side lines which were run to a closure on the "main", or boundary, stadia line was 7 000 m., or a total of 826.5 km. (513.7 miles) and 18 courses per line; that, assuming the "main" line to be correct—which it was not (see Table 17)—these side lines closed on it with an average error of 1 in 750 in distance and of nearly 23″ per angle turned. These last

* "Theory and Practice of Surveying," by J. B. Johnson, 16th Edition, 1906, p. 280*a*.

two may be compared with the writer's closures (see Table 7) of 1 in 900 for distance and less than 5″ per angle turned, on 186 lines aggregating 1 051 km., or, rejecting 9 lines (see Table 8), a closure of 1 in 990 on 177 lines aggregating 979 km.

TABLE 16.—WORK ON INTERNATIONAL BOUNDARY WEST OF EL PASO, 1892–93.

(1) No. of lines.	(2) Total length.	(3) Average length of sights.	(4) Average number of sights per line.	(5) Error of closure: 1 in	(6) Azimuth error per angle read
29	111 823.2	253.0	15.2	553	29.0″
49	280 706.8	356.7	16.1	782	23.0″
28	290 633.9	437.7	23.7	817	18.8″
12	143 352.0	580.4	20.6	786	21.5″
118	826 515.9 7 004 = average length of lines.	386.2	18.1	752	22.7″

The writer has had occasion to check with a steel tape three of the distances between monuments on the boundary west of El Paso, and the result of this checking is given in Table 17.

TABLE 17.—CHECKING DISTANCES BETWEEN MONUMENTS.

(1) From Monument:	(2) To Monument:	(3) Stadia (Barlow).	(4) Chained (Follett).	(5) Difference.	(6) Ratio of error: 1 in
84	85	3 983.66	3 977.6	+6.06	657
85	86	4 449.98	4 444.1	+5.88	756
92	93	4 460.52	4 462.85	—2.33	1 922
		12 894.16	12 884.55	14.27	904

The arithmetical sum of the differences is used. The signs only go to show that sometimes the stadia distances over-ran and sometimes fell short.

The stadia distances in Table 17 are taken from Column 2 of the table on page 36 of Part 1 of the Barlow Report, and it is there stated that the distances are those of the United States Section. The distances between Monuments 84 and 85 and Monuments 85 and 86 were measured with a steel tape on level ground by Mr. Ross Allison in February, 1908. Mr. Allison had just completed several months' work on a precise line in the El Paso Valley and, being a very careful man, he naturally took great pains with his chaining. There is no doubt that it checks within 1 in 10 000. The distance between Monu-

ments 92 and 93 was measured on August 22d, 1906, by Mr. Zayas and the writer. The ground was rolling. The chaining was carefully done, and probably will check within 1 in 5 000 or 1 in 6 000. Table 17 would indicate that the "main" stadia line of the Barlow Survey may not check any better than his side lines, and, as the latter were controlled by the former, considerable doubt is thrown on the trustworthiness of the results given in Table 16. Certain combinations of errors would give results better than there shown, and others would give worse ones.

As illustrating further the possible errors which may have existed in the Barlow "main" line, attention is called to the distance between Monuments 85 and 86. The table referred to in the Barlow Report gives the United States stadia distance as 4 449.98 m. and the Mexican as 4 437.85 m., a difference between the two of 12.13 m., or 1 in 366. The mean was assumed to be correct. The writer does not know whether it or the original Barlow distance was used in balancing adjacent stadia traverses. Similar differences will be found at various places in the table. A cursory examination discloses twenty places where the United States and Mexican distances between adjacent monuments differ more than 1 in 400 and seventeen more where they differ more than 1 in 500. The worst ratio of differences is between Monuments 185 and 186 where the distances differ 1 in 270 (the two distances being 4 496.74 and 4 513.41 m.). The worst absolute difference is between Monuments 105 and 106, where the difference is 21.5 m. and the ratio of differences is 1 in 301 (the two distances being 6 492.22 and 6 470.68 m.). The first is in broken country and the last is on a level prairie.

Attention is not called to these discrepancies with the intention of criticizing the work of the Barlow-Blanco survey, because the exact distances between monuments was of no particular importance, so long as they were placed on the boundary, but for the purpose of showing the uncertainty of the data in Table 16. This table has become a classic, and it is only right that those who use it should know just how much dependence can be placed on it.

On the Barlow work, great exactitude was attempted in the stadia work by the use of rod levels for holding rods plumb, stadia reduction tables, frequent interval determinations, studies of the boiling of the air caused by heat waves, and of differential refraction, etc., etc. All these things not only consumed valuable time, but gave a fac-

titious value to the results. They naturally engendered the belief that the work was much closer than it really was. It is disappointing, to say the least, to find that distances which are given to centimeters are really from one to several meters in error. No man can read by stadia a distance to tenths of a meter at distances of more than 50 m. He may read to half a meter up to 200 m. or so, but beyond that he is lucky if he gets within a meter of the true distance. The centimeters of the Barlow-Blanco distances come from the use of reduction tables which are computed to centimeters from observations which could, at the best, only go to half meters, or in very short distances, tenths of a meter.

Johnson states* that the results obtained on the U. S. Lake Survey are perhaps a fair average for various conditions. On that survey the errors of closure of 141 meandered lines, averaging $1\frac{1}{2}$ miles each, or 210 miles (338 km.) averaged 1 in 650. The official limit was 1 in 300.

Comparison is invited between Tables 7 and 8 and Table 16. The physical conditions under which the two sets of lines were run were about a "stand-off". The Barlow lines were run in a country which was very rough in places, but was practically free from brush, and where the air conditions were generally fair, except in the mountains, where they were usually good. The lines of Tables 7 and 8 were all in a flat country favorable to good work, but, aside from the river, were in brush and with poor air conditions at times. The three tables indicate that much more depends on the expertness and carefulness of the instrumentman than on rod levels and reduction tables. The grade of the transits was the same on both surveys.

The writer believes that his thesis—that stadia work as usually done is burdened with needless refinements—is sustained by the results of this work when compared with those obtained by the more laborious methods.

Rate of Progress of Stadia Work.—The rate of progress on the stadia lines varied greatly. The fairest way of showing it is to give the number of shots per day. These are as follows:

River topography	......	150 to 200	shots per day.
Texas "	......	100 to 150	" " "
Mexico "	......	90 to 125	" " "

The river party covered from 3 to 5 km. (2 to 3 miles) per day.

* "Theory and Practice of Surveying," p. 280.

Unit Costs.

The total cost of the field operations, from October 1st, 1910, to June 30th, 1911, including all transportation charges and repair of outfit, was $22 400.

It is impossible to divide this exactly among the various classes of work. About 75% can be properly distributed. This has been done, and then the remaining 25% has been divided up in about the same proportion as the 75%, and the following results:

Precise line	$4 000
Primary level line	750
Topography	13 150
Ties to bancos, marking bancos and building monuments	4 500
Total	$22 400

The precise line cost includes half of the computer's time. The topography cost includes the time of two draftsmen and the note caller. The banco ties cost includes half of the computer's time.

The precise line party ran and checked (including lines run to reference points) 155 miles of line, which cost $25 per mile. This seems excessively large. No comparison with similar work can be found.

The level party ran and checked 155 miles of primary levels, which cost $5 per mile. This is reasonable, and compares favorably with the cost of similar work in other places.

The topographers covered 375 sq. miles, at a cost (for the work done on this trip) of $35 per sq. mile. There had been, however, 79 bancos surveyed, where old topography was available. Of course, the river had to be re-surveyed in front of the bancos. The average area of each of these to the center of the old channel, was about 145 acres. The survey extended beyond this, so that each banco survey represented, probably, ½ sq. mile, or 40 sq. miles in all, leaving 335 sq. miles which were covered by this survey, at a cost of $39 per sq. mile. No unit cost can be calculated for the banco ties, etc.

It must be remembered that the topography did not cover the whole ground thoroughly, but consisted in the tracing out of special features, such as the river channel, overflow bank, roads, ranches, lagoons, etc.,

hence the foregoing cost is not properly comparable with contour surveys which cover all the ground with equal thoroughness. Such may cost two or three times as much per square mile as did this and still be economically done.

The Barlow survey covered 1 750 sq. miles, at a cost of $85 500 plus 40% for "General office and Commission expenses", or $119 700—or $68 per sq. mile. The two surveys probably covered the ground with about the same degree of thoroughness, but the physical conditions were much more severe on the Barlow work.

AMERICAN SOCIETY OF CIVIL ENGINEERS

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PAPERS AND DISCUSSIONS

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THE PHILOSOPHY OF ENGINEERING.

Discussion.*

By Maurice G. Parsons, Jun. Am. Soc. C. E.†

Maurice G. Parsons, Jun. Am. Soc. C. E. (by letter).—The writer's paper has fallen into the hands of men more worthy than he, who have treated it from various points of view, with the matureness of thought which comes from decades of practice, and, as masterly theses on kindred subjects have recently appeared elsewhere, little could now be added advantageously by any one. On the subject of the money trust, however, which at present incurs the disfavor of several factions, the writer desires to make some closing remarks. Mr. Parsons.

Past abuses by this elusory organization must be corrected, not from without, but from within. Only the money trust itself, prior to a much more serious stage of the malady with which the nation is afflicted, can temper its injustices. Voluntarily, when it comes under the control of men big enough to be more generous, it will allow adequate compensation to all producers; for its own welfare, private initiative will be encouraged, the man with a good commodity will be given opportunity to find a market, and will receive a fair reward. Under a stronger and more enlightened money trust, inhuman greed will be peacefully diminished; capital, as capital, will consider the substantial needs of the people, its retainers; and stock exchange juggling will cease. Through the merest common sense, it will correct its many abuses.

Moreover, the control, by a small ring, of much ready money is necessary in order that tremendous undertakings may be accomplished, that new territory can be vitalized as the result of world-wide prolonged conscientious search for that which is most promising. The

* Continued from August, 1913, *Proceedings*.

† Author's closure.

Mr. Parsons. present crisis of international tension, financial stringency, political and social unrest, could be passed quickly and safely if all bankers, in a spirit of mutual interest, would get together with that end in view—if there were a firmer and better money trust.

Nor is precedent lacking for such a financial authority: The Edison Laboratories are not content with the resources of any one locality. If something is wanted, it is searched for, everywhere, at great cost. As a result of world-wide investigation with central clearing-house reports and decisions, the Edison Laboratories produce handsomely for the use and convenience of man. In political government the individual is not a large enough unit; neither is the family nor the state. We have a national head and even international formalities. Similarly, the individual is normally merged financially in the local community. Next in order, is a sub-control of local affairs, then an accumulating of resources in some particular bank, and so on.*

Must we not have admittedly a supreme authority in matters of finance, a coterie of international bankers, with its hand on the pulse of the world?

In a broader conception, these men would be members of more than a commercial clearing house. Money is simply a medium of exchange and standard of value. It represents stored-up life, and as such is to be regarded with awe. Those who control it control the lives of the people and the welfare of the nation. All differentialities of human interest are not reduceable by man, with his human frailties and only human knowledge, to precise amounts of money. It is necessary, therefore, that these men have, in addition to ability, training, experience, and judgment, a broad human understanding. Furthermore, they must be men who can oppose with an iron hand, if need be, improper tendencies. Study should be given by them to such matters of national interest as the high cost of living, the pernicious influence on morality of rag-time thought, speech, song, dance, and dress, the fact that in so many cases *viri* has given place to *homo*. World patriots of finance, in the interests of capital, could do naught but afford an "even break" and a "square deal" to each and all, for, to secure perpetually a maximum present worth of net incomes, there must be happiness, loyalty, industriousness, integrity—all the superb qualities—on the part of all the people. Industry should be for the use and convenience of man, for, in the last analysis, it is not bank accounts, but lives and souls, which count. The engineer of to-morrow will be, let us hope, a human engineer.

It were an easy matter to enlarge on the powers of the money trust until it absorbs every function of government. We should then have to ask ourselves where we were coming out; what these all-

* The reader is referred to an article on the failure of the First-Second National Bank of Pittsburgh, in the *Literary Digest*, July 19th, 1913.

Mr. Parsons.

powerful men might do; and how they would be chosen. Under a pure democracy, we should run the danger of having for our rulers a prize collection of demagogues. With a restricted democracy, we might gradually be overpowered by an oligarchy serving its own end. An inherited monarchy would sometime fall to an imbecile.

As it is to-day, we have a system that works, and no great need exists for a radical departure, although some precautionary measures should be taken. The Reclamation Service and the Department of Commerce and Labor, the one spending many millions of dollars, guided presumably by the ideal theory of investing our money where, when, and in what amounts, it will do the most good, the other serving the people in a sociological sense—these two divisions of government might unite forces, developing into a department-controlling industry, but it is hardly likely that such is a necessary step. We have now a government to look after our many needs and troubles. We have financial rulers (the real rulers) deciding our commercial issues. We have individual strong men. On occasion, they are at variance, and unavoidably so, for it is rare for even only two minds to be in perfect accord.

What will be the new philosophy of engineering? Will there be an industry for profit, an industry for abuse, an industry for profit and use, or will there be chaos? We are facing a big problem; one for the individual, educator, and engineer to solve. Social, political, educational, moral, and economic conditions are changing. The concentration of population presents its own difficulties. With all our necessities and luxuries we clamor for more, in the belief that some day we shall have enough to make us happy and industrious. The vast resource of opportunity of the past century has passed with it. Competition from now on must be for quality. Peace prevents the elimination of the strong, sanitation and amelioration of conditions preserve the weak, so that the strong become stronger, the weak, weaker, and competition increases under an artificial selection. This means more bitter disappointment to more losers. The struggle for existence is a relic of the past, but in this game of life, what strife may come? The question is not one of organization, but of philosophy; not of how much property is accumulated, but of the use to which it is put; not of system, but of men. We need a closer harmony between existing working parts.

The big task before the engineer to-day is to help the world out of the uncertainties of complexities, theories, and tendencies—the work of his hand—into a new condition of stable equilibrium. This means sober, industrious, healthy, educated, courageous individuals, in short, good citizens. It means, also, broad-minded, far-sighted, unoppressive industry, good business. A strong and wise government

Mr. Parsons. is necessary. Perfect team work between business, government, and people is called for. Fundamentally, the need is always men.

"God give us men! A time like this demands
Strong minds, great hearts, true faith, and ready hands;
Men whom the lust of office does not kill;
Men whom the spoils of office cannot buy;
Men who possess opinions and a will;
Men who have honor, men who will not lie;
Men who can stand before a demagogue,
And damn his treacherous flatteries without winking!
Tall men, sun-crowned, who live above the fog
In public duty and in private thinking:
For while the rabble, with their thumb-worn creeds,
Their large professions and their little deeds,
Mingle in selfish strife,—lo! Freedom weeps,
Wrong rules the land, and waiting Justice sleeps." *

* "Wanted", by Dr. J. G. Holland.

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PAPERS AND DISCUSSIONS

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DERIVATION OF RUN-OFF FROM RAINFALL DATA.

Discussion.*

By L. J. Le Conte, M. Am. Soc. C. E.

L. J. Le Conte, M. Am. Soc. C. E. (by letter).—The formula presented by the author is very ingenious and seems to fit the cases considered with surprising closeness. Where the basin is for water supply and power purposes, however, the writer would particularly caution the young engineer against making any practical use of the long average run-off, which is that furnished by the formula. Mr. Le Conte.

The water supply storage reservoirs at and near San Francisco, Cal., have been in constant use for 43 years, hence the practical results obtained are very interesting. The long average rainfall is 40 in., and the long average run-off is 8 in., or 20 per cent. The important fact remains, however, that at intervals of 10 or 12 years there are 3 years in succession in which the rainfall is only 18 or 20 in., and is distributed so uniformly that the thirsty ground takes it all, and, as a result, there is absolutely no run-off for 600 days or more. The reservoirs, therefore, have to be large enough to hold a 3 years' supply without any possible hope of replenishment.

The same important feature is noticed on the Sudbury water-shed,† where the record for 37 years shows a long average yield of 1 000 000 gal. per day per sq. mile of water-shed; but, during the three successive years, 1909, 1910, and 1911, the average yield was only 550 000 gal. per day per sq. mile. This is practically the limit of usefulness for this water-shed. The record shows that in 1888 the average yield was 1 700 000 gal. per day per sq. mile of water-shed, but as this only happens once in about 25 years, this isolated fact has no practical value for water-supply purposes.

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* This discussion (of the paper by Joel D. Justin, Assoc. M. Am. Soc. C. E., published in August, 1913, *Proceedings*, but not presented at any meeting), is printed in *Proceedings*, in order that the views expressed may be brought before all members for further discussion.

† Twelfth Annual Report, Metropolitan Water and Sewerage Board of Massachusetts 1912, p. 58.

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PHYSICAL VALUATION OF RAILROADS.
Discussion.*

By Messrs. Halbert P. Gillette, J. E. Willoughby, S. Whinery, F. Lavis, William W. Crehore, Alexander C. Humphreys, and J. H. Gandolfo.

Halbert P. Gillette, M. Am. Soc. C. E. (by letter).—Appraisers of railways and other public utilities differ radically on many important principles, such, for example, as to the propriety of using present unit prices or prices that are the weighted average during a term of years. The writer has found that most of these differences of opinion spring from differences in hypotheses as to the political status of public utilities. Analysis discloses two distinct hypotheses, or theories, which, though rarely reduced to words, exist in more or less definite form in the minds of appraisers. These two theories may be called: Mr. Gillette.

1. The Agency Theory;
2. The Competitive Theory.

According to the Agency Theory, every public service company is a public agent authorized to render certain kinds of service, and entitled to be recouped for all reasonable expenditures and costs plus a fair profit.

According to the Competitive Theory, every public service company is authorized to render certain kinds of service, and is entitled to collect what the traffic will bear under more or less competitive conditions.

It is needless, perhaps, to point out that, until recent years, American railways were not subjected to regulation according to the Agency Theory, but were "regulated" by the natural laws of commerce. Gradually, however, the Agency Theory of regulation has been evolving, but has not yet attained general application. We still see the Federal

* Continued from September, 1913, *Proceedings*.

Mr. Gillette.

Government attempting to apply the Competitive Theory to railways, by forcing the dissolution of so-called "competing lines"; while, at the same time, the most "progressive" States are attempting to apply the Agency Theory. The Public Service Commission of the State of Washington recently authorized the consolidation of certain telephone companies, and scarcely was the consolidation effected before the Attorney General of the United States began action, under the Sherman law, to "unscramble" the consolidated companies.

Two political theories, therefore, are now struggling for supremacy; and it happens that these two theories vitally affect the principles to be applied in the appraisal of railways and other public utilities.

According to the Agency Theory, the "value" of a public utility property is the reasonable actual investment of capital in the property. This includes the investment in the physical property and the investment in the "residual development cost" (the unrecouped deficit in fair return on the investment).

According to the Competitive Theory (when logically applied), the value of the property is the cost of its reproduction at present prices, minus the capitalized difference in annual cost of production with the existing plant and with the most modern plant which would give the same service, plus the capitalized value of the profits derivable from the plant during the remainder of the company's franchise or charter. Briefly stated, this "value" is depreciated value plus franchise or going concern value.

Although there is a large element of injustice in suddenly dropping the Competitive Theory—a theory under which railways have so long operated and under which so many stockholders have invested—the recent history of public regulation makes it quite clear that the Agency Theory is destined to be adopted. In the transition period, however, we shall have a mixture of the two theories—a sort of compromise theory.

The State which has gone furthest toward the adoption of the Agency Theory is Wisconsin. We find the Wisconsin Commission, for example, including the "going value" or development cost (equal to the residual deficit in fair return) as a part of the total "value" for rate-making purposes. Also, it refuses to allow the cost of pavement laid over water pipes, unless the water company itself has paid for the pavement. Likewise, it averages unit prices over a term of years, and, where construction has been piecemeal, it uses piecemeal costs. Each of these four rulings is directly in accord with the Agency Theory, and directly opposed to rulings by some Commissions and Courts in other States where the Competitive Theory may be said to prevail.

Mr. Wilgus gives powerful reasons favoring the use of cost of reproduction new as the "value" for rate-making purposes. The recent

decision of the U. S. Supreme Court in the Minnesota Rate Case is adverse to this contention. The Court rules that depreciated value must be taken as the "value" for rate-making. Unfortunately, the railways involved in the Minnesota Rate Case presented their side so poorly that the Court did not have either adequate evidence or well-prepared argument on many vital points. Thus, there was no evidence as to the development cost of the railways. Again, depreciation was calculated by the State's engineer according to the "straight-line formula", and the railways did not have the acumen to put "the boot on the other foot" by demanding that an annual depreciation fund be calculated on the same basis. Had this been done, it would have been shown to the Court that the current maintenance expenditures were not sufficient to cover both the repairs of parts and the depreciation of entire plant units. Several other important errors were made by the railways in presenting their case, but these two are mentioned merely to indicate that the precedents established in the Minnesota Rate Case should not be taken as final by any means. Mr. Gillette

The author is entirely right in saying that depreciated value is not a rational basis for rate-making. Under the Agency Theory, a new public utility company starting to-day would be entitled to a fair return on its actual investment, and it would lead to "confusion worse confounded" were a part of that investment "written off" each year because of depreciation. The thing could be done, but no useful purpose would be served by doing it, while, on the contrary, rates of charge for service would fluctuate with an ever-changing depreciated value. There is a good deal of "horse-sense" in the illustration used by an attorney who argued that the price of milk is not a function of the age of the cow, growing less as the cow grows older, until it would be almost given away in the latter days of the cow's life. What the provident owner of a cow does is to charge a price for milk which will give a fair return on the investment (not on the depreciated value) plus enough to cover "operating expenses", including depreciation. Should the cow be purchased by another dairyman, it is true that he would pay for it on a depreciated basis, but the depreciated value would be such that, during the remainder of its life, the same price for milk would yield both a fair return on the lower price paid for the cow and enough to cover "operating expenses", including the remaining depreciation.

The Agency Theory applied to new railways will unquestionably lead to the use of the actual cost of the property as the rate-making basis, for it is not rational to burden the present, in order to relieve the future, patrons of the road, as would occur if depreciation were "written off" and rates were based on depreciated value. But what shall be said of the application of the Agency Theory to old railways which now,

Mr. Gillette. for the first time, come under the actual application of this theory? The writer believes that justice demands the most liberal treatment of public utilities, particularly in this transition period. Certainly, it is not liberal to appraise for rate-making any of the property of a railway at less than its cost new. Moreover, to use the depreciated value for old roads would be to apply a policy that would not be applied to new roads, in rate-making. Of course, it may be contended that the owners may thus be paid twice for accrued depreciation, because they have already taken out in dividends enough to yield a fair return plus enough to cover the accrued depreciation. Even were this so, we should not lose sight of the fact that the present owners were not the original owners; and they had no way of foreseeing the advent of this new theory—the Agency Theory. The writer, however, is confident that a careful analysis of the ledgers of all railway companies, as far back as accounting records are obtainable, will disclose that the residual development cost is sufficient to wipe out all accrued depreciation, and more too. Development cost is not, as commonly supposed, a matter of ancient history; for the truth is that almost every extension of a railway involves development cost (deficit in fair return). No sooner has the average railway "nosed out" of its development period than it makes an addition or improvement which plunges it into another development period, the surplus from the old investment being swallowed by the deficits of the new. Can there be any doubt, for example, that the great, new terminal of the Pennsylvania Railroad, in New York City, is a cause of deficit at present, in so far as that terminal is concerned?

This matter of development cost leads to another phase of the subject of appraisals. Mr. Wilgus says:

"With rare exceptions, it is extremely doubtful that the books and records of the railroads of the United States will be found to be dependable for the purpose of ascertaining present-day fair values. Only in recent years have cost accounts been kept in a uniform and complete manner, and even then the almost universal tendency has been to understate charges to construction, and to additions and betterments."

The writer does not agree with the author, either that correct railway accounting is of recent origin or that the records are not dependable as a guide for appraisal purposes. He recognizes that old records are not always complete, but the gaps are surprisingly few in most cases, and not difficult to fill by estimates which cannot possibly alter the totals by very appreciable amounts. The railways of America would err seriously were they not to conduct the most thorough analysis of all their old records. Their first great error would be their failure to demonstrate what their development costs have been. Development cost (that is, deficit in fair return) cannot be proved satisfactorily except

from accounting records. Their second great error would occur through failure to find all the elements of physical value created by necessary expenditures which cannot be seen with the eye. This, it may be said, can be covered by adequate allowance for "contingencies"; but, who knows what is adequate? The writer had occasion to appraise a large property which had been previously appraised by an engineer who had added 10% for contingencies, but whose appraisal still fell short, by 20%, of the actual cost of the property. Failure to hunt for and analyze the accounting records was at the bottom of this serious under-estimate. The company was a consolidation of more than a dozen smaller companies, and the earliest accounting records were nearly 25 years old. Were the earliest of these records valueless in a present-day appraisal? Some, it is true, were of minor worth, but they covered minor elements of value. Nearly all the records served to throw light on elements of present-day value which, otherwise, would not have been discovered. Mr. Gillette.

In this connection, it may be added that the maintenance records should also be analyzed, for it is true, as the author says, that perfectly correct accounting has not invariably existed. Minor expenditures, which should have been charged to property account, have not infrequently been charged to maintenance, and the sum of these minor expenditures thus charged may be quite considerable. Conversely, abandoned or superseded property has not always been charged to maintenance, but occasionally has remained in the property account. This is particularly true of abandoned railway roadbed. A careful analysis of the construction and maintenance accounts, guided by the appraisal of physical property now visible, will result invariably in the discovery of values which otherwise would not appear in the appraisal. Not only will additional quantities be thus found, but larger unit prices will be deduced; and in this connection it may be well to add that unit prices should not be those obtained under rather favorable conditions, but under average conditions. A favorable condition, for example, would be "summer work". Winter work is an unfavorable condition, but one which is often imperative in railway construction, in order to keep down the interest and development cost. The history of the Northern Pacific extension to the Pacific Coast shows that at times almost as many men were engaged in shoveling snow as in shoveling earth. It was such conditions as this, coupled with other unforeseen difficulties, and followed by a much greater development cost (deficit in fair return) than was anticipated, which threw the Northern Pacific into bankruptcy not long after its completion to the Pacific Coast.

In recent appraisals made by the writer, it has been his practice to allow 5% for contingencies where the construction ledgers were all available, but where the original records of physical quantities were

Mr. Gillette. rather meager. If both ledgers and engineering records of quantities are fairly complete, the allowance for contingencies may safely be eliminated, provided liberal unit prices are used. It should be remembered that a contingency factor is automatically introduced whenever liberal prices are adopted.

Regarding brokerage fee, the writer agrees with the author in its inclusion as a part of the cost; but, of course, the same end may be obtained if the rate of fair return is made high enough to allow for all the discount on bonds, including the brokerage fee. This last view was that taken by the Washington Railroad Commission when the writer was its chief engineer, and it is the view now taken by most of the State commissions.

Interest during construction should certainly be calculated on all land as well as on other physical property. The writer was not in direct charge of the appraisal of the land for the Washington Railroad Commission, and, therefore, did not calculate any of the overhead charges on it. In fact, no overhead charges on the land appear in the final land values fixed by the Commission. It is possible that overhead costs on land were omitted, or else that they were included in the "right-of-way multiples". The writer calls attention to this particular case for two reasons: First, because he believes it to be a mistake not to put the entire appraisal of all railway property under the direction of the engineer in charge. Second, because the writer's total overhead charges on the plant, exclusive of land, have often been divided by the sum total of plant, inclusive of land, giving an erroneous result when taken to indicate the total percentage allowed by him for overhead charges. The author of one book on appraisals and many writers of articles have unwittingly been led into this error.

This is not the only kind of error which has been committed by writers in comparing the percentages for overhead costs allowed by different appraisers. For example, one appraiser may estimate 5% for business management, and another would include this item in the unit price and, therefore, not show business management as a separate overhead cost. Many railway construction contracts have been entered into with a managerial contractor on a "cost plus 5%" basis. The recorded contract prices are then sub-contract prices. An appraiser may either use these sub-contract prices and subsequently add 5% as a business management item among other overhead costs, or he may increase all the sub-contract prices by 5%, calling them contract prices, and show nothing separately for this business management. One needs to know the method used by an appraiser in arriving at his unit prices before one can interpret correctly his estimates of overhead costs. Not a few appraisers "bury" may of the overhead costs, leaving but a part to appear specifically as such in the final summary. The present prac-

tice of the writer is to show all overhead costs separately. They commonly total fully 25% of the cost of the "unloaded" property. Mr. Gillette.

As previously stated, the Washington Railroad Commission restricted its engineer to a consideration of plant value only, exclusive of land. Hence, working cash capital, brokerage fee, and development cost did not appear among the items estimated by the writer. The Commission listened to more or less testimony by the railways on "going concern value", etc., but announced its conclusions without stating any definite theory as to non-physical values. This failure to delegate to its engineer the study of all elements of value is one which the writer regrets exceedingly. The railways were equally mistaken in thinking that a determination of non-physical value was not an engineering problem; consequently, they did not make a satisfactory presentation of their case as to non-physical values. In all subsequent appraisals, the writer has insisted on having full charge of the entire appraisal, including determination of development cost, land values, analysis of accounting records, etc. Some one with technical training should always be placed in full control of any appraisal which is to be used as a basis for rate-making. If an example were needed to illustrate this point, it could be found in the Minnesota Rate Case, where the railway companies erred so seriously through not having the entire technical part of their case directed by engineers. The natural tendency of a railway company is to ask each department to prepare its part of the data, and the result is a more or less confused mass of facts—often facts which conflict because of their incompleteness or because of the incorrect use of terms. In the Minnesota Rate Case, both "right-of-way multiples" and "overhead charges" on land were thrown out by the U. S. Supreme Court. The inconsistent use of words and lack of proper definitions of terms account as much as anything for this erroneous ruling, for the Court was attempting to use symbols which it did not fully understand, and did not understand because they were not clearly and properly defined by any witness.

It would seem that attorneys would always see to it that at least the definitions of technical terms would be precise, and that witnesses would adhere to such definitions; but attorneys themselves are often lost when it comes to the use of engineering and other technical language; so that, if a technical rate case is to be presented properly to a commission or a Court, it should be presented by engineers and by those who have been taught by engineers to use technical terms properly and always with the same significance.

When railway appraisals first came to be used as a basis for rate regulation, all, except engineers, regarded an appraisal as being somewhat analogous to a merchant's inventory of stock on hand—a very simple, though often laborious, process. Gradually it has become evi-

Mr. Gillette. dent, even to non-technical men, that an appraisal for rate-making purposes is exceedingly technical and complex. When it is realized, also, that rate-making based on cost is even more technical than appraising a property, we shall have an end to the "hot air" testimony of rate experts who are experts only in fixing rates "as high as the traffic will bear."

Appraisal and rate engineering has already become one of the many branches of engineering. The engineering specialist in this line should be primarily a logician, skilled in the use of language and in the science of reasoning. He should be thoroughly acquainted with the general principles of economics and particularly with the principles of engineering economics. He should be well informed as to the decisions of State and Federal rate-regulating commissions, as well as Court decisions bearing on valuations and rates. He should be personally acquainted with specialists in many lines, so that he may select men competent to give any desired information. He should be thoroughly grounded, not only in the principles of accounting, but in the mechanical details of public utility accounting. He should be an incessant student of the new phases of his specialty and of unit costs of construction and operation. Executive ability is also essential to him, but need not be of as high an order as that required of one who is constantly directing large enterprises. It is needless, perhaps, to add that his character should be such that he would make an impartial judge. Obviously, no man can attain the ideal in this, or in any other, branch of engineering; but, at least, those who employ appraisal and rate engineers should aim to secure men who are idealists rather than opportunists, for this is not a profession where mere advocates will survive.

Mr. Willoughby. J. E. Willoughby, M. Am. Soc. C. E. (by letter).—The writer is in accord with Mr. Wilgus in his conclusion "that the cost of reproduction new appears to be the only measure of physical value that places all railroads on the same plane, and the only one that provides for the inclusion of every element of cost that enters into the creation of a going railroad," but cannot agree that he has taken the correct view of depreciation.

It is true that in a well-maintained railroad the accrued depreciation in track and structures does not lessen its capacity as a carrier to perform the work for which it was created, nevertheless, the monetary value of a railroad with track and structures representing 55% of the service that would be obtained from a railroad with all its parts new (all other conditions being unchanged), is less by the amount of the depreciation. Of the capital originally placed in the track and structures, 45% has been consumed. The replacement of this capital can be effected practically only by the creation of a depreciation ac-

counting with a credit which at all times will be equal to the accrued depreciation. The depreciation fund is properly accumulated from year to year as an operating expense, and is to be regarded as an item of value (just as working capital is) which enters into the total value of the railway property whether that value is being ascertained for the purposes of sale or of rate-making. The value of the physical features of any railway property at any time is: Mr. Willoughby.

The total cost of reproduction new, less the accrued depreciation on those parts so affected, plus the accrued appreciation on those parts so affected, plus the amount of the fund provided for the renewal of the parts on which depreciation has accrued.

In many of the existing railways a depreciation fund, if set up now in the accounting, would cause to be shown a profit and loss deficit which would properly reflect itself in a deduction from the market value of the stocks. The meaning would be that, in the past years of the railway's operation, a definite portion of the capital originally put into the track and structures has been consumed instead of being charged out annually as an operating expense. Certainly, the same arguments which caused a depreciation accounting to be set up for rolling stock, apply to the track and structures.

It has been advocated that inasmuch as the annual repairs and renewals, a part of the annual operating expenses, are sufficient to replace the amount of the annual depreciation, a depreciation accounting is useless. Such a view ignores the capital consumed during the early years of the railroad's operation, when the annual repairs and renewals did not replace the annual depreciation.

There is unanimity of opinion that the accrued appreciation in the roadway and right of way should be taken into consideration in fixing the cost of reproduction new. When that is done, it is proper to consider also the depreciation.

The writer believes that obsolescence should be considered as a form of depreciation, because depreciation, in the sense used in connection with the re-valuation work, covers any deterioration of the part affected from any cause by which that part has a less capacity to perform the work for which it was created.

S. Whinery, M. Am. Soc. C. E. (by letter).—The author refers to the widely different opinions and practices of engineers, appraisers, and the Courts in the valuation of land used for right-of-way and other railroad purposes. Such differences are doubtless largely due to the fact that the purpose for which an appraisal is made controls the point of view to a greater extent than in any other class of railroad property. This fact seems not to have been generally recognized and given proper weight in appraisals and in discussions of the subject, particularly by the public. Mr. Whinery.

Mr. Whinery. The importance of the fact that the purpose for which an appraisal is made must control the methods and values used, was early impressed on the Commission appointed in 1909 to re-appraise the railroads and canals of the State of New Jersey.

The Joint Resolution under which the work was undertaken, required that the Commission should prepare and report a "true and complete inventory and appraisal of the true value" of the railroad and canal property of the State, and, further, though rather incidentally, stipulated that the valuation "shall be in a form available for the purpose of taxation under existing laws".

In their first (progress) report, the Commissioners stated:

"It is not positively stated in the Joint Resolution that the valuation is to be solely for taxation purposes. A true and complete inventory and appraisal of value seems to be called for regardless of the purpose for which the valuation is made. But the term 'True Value' is not definite, since the value of any property varies with the standard of value applied and the point of view from which it is judged. From the very nature of railroad property and the manner in which it is held its market value, in the sense in which that term is applied to other property, is difficult to determine. The commercial value of a railroad is usually determined by its net earnings and the returns made to its owners, quite independent of its cost or of the value of the property it possesses. Frequently there appears to be no close relation between the cost of a railroad and its commercial value. Valuations for the purpose of fixing rates, or for determining proper rental, or terms for joint running operation may also be quite apart from the commercial or the intrinsic value. The value of the franchises and the other intangible property of a railroad may be differently appraised according to the purpose of, or the point of view from which the appraisement is made. Finally, the value of this class of property for taxation purposes may be quite different from any of those named above. It seems, therefore, impracticable to apply any single valuation of the railroad and canal property of the State to more than one specific use, and if this be true, it follows that the purpose of the valuation should be determined upon before an appraisal is made.

"In view of all these conditions, and after a careful consideration of the Joint Resolution, and in view of the necessity of establishing the particular kind of value we are called upon to determine, your Board has thought it best to appraise the various railroad and canal properties from the viewpoint of the use of the appraisal mainly for the purposes of taxation."

From the wording of the Resolution, it may fairly be inferred that although the members of the Legislature had in mind the use of the valuation chiefly for purposes of taxation, they were under the impression that the phrase, "a true and complete inventory and appraisal of the true value of railroad property", could be applied to any purpose for which the value of the railroad and canal property of the State might be needed.

There is abundant evidence that the same idea is held by a majority of the public, including members of Legislatures and of Congress. It is important for many reasons that the public mind should be disabused of such erroneous conceptions, and it should be one aim of public discussions of the subject to educate the public on this point. Mr. Whinery.

In fact, there is great need that the public should be educated on the whole subject of the valuation of quasi-public property, and for this reason it would be well that technical discussions of the subject should be sufficiently elementary, and couched in such language that any intelligent citizen could read them understandingly; and that a greater effort should be made to give these discussions as much publicity as possible.

The question of the proper valuation of railroad real estate is complicated and made more difficult by the widely varying elements which enter into the original cost of the property and the conditions under which it was acquired and is held by the railroads. These elements are of such character and of such magnitude that the ordinary standards of fair market price are usually only partly applicable in determining the value of the right of way, either at the time it is acquired or later. Even where the cost of the property to the railroad is ascertainable, it is not always a correct basis of valuation for some of the purposes for which an appraisal may be required.

In discussing the subject, it is the purpose of the writer to deal chiefly with broad general principles, but to consider these somewhat more in detail than has been usual, and to review the various elements of cost and value that enter into an appraisal, for any specific purpose, of right-of-way land. It seems to be necessary, in the interest of clear statement and argument, to recount facts and principles which are neither new nor novel, and the discussion, therefore, may be somewhat tedious to the reader. The writer will attempt to deal with the matter from what he conceives to be a sound and reasonable business standpoint, with little reference to statutes and Court decisions, which may vary in different States. In any specific case, the laws and Court rulings controlling in that locality must, of course, be complied with, but sound principles of justice and equity must be the fundamental basis of all appraisal work.

What will be said refers more particularly to right of way proper, rather than to lands acquired and held by railroads for terminals and other improvements. The status and basis of valuation of these latter may, and usually do, require special consideration and treatment.

Right-of-way land is held by the railroads under one of two forms of tenure: ownership in fee simple, or some form of easement. In the former, absolute title to the property is conveyed to the railroad; in the latter, only certain rights to occupy and use the property for

Mr. Whinery. a specified time or purpose are acquired. The distinction is clear enough in theory, but not always in practice. A conveyance in fee simple may contain conditions, as a part of the consideration, which may cause the property to revert to the grantor, or which may be a continual menace to the title to the extent that it amounts to little more than an easement; and an unconditioned, perpetual easement may be equivalent, for practical purposes, to ownership in fee simple. The tenure under which the land is held by the railroad, therefore, is a matter to be given due weight in its appraisal; but, for the purposes of outlining general principles in this discussion, it will be sufficient to consider only right-of-way land owned in fee simple by the railroad.

Into the consideration, or price paid for a typical right of way, however that price may be determined, three principal elements usually enter:

1. The fair market value of the land.
2. Permanent damages to the remaining property from which the right of way is severed.
3. Temporary damages.

To the sum of these items must be added, to find the actual cost to the railroad:

4. Expenses incidental to the acquirement of the property.

Permanent damages are such as permanently impair the value of the property, a part of which is taken, for the uses to which it is, at the time of the transaction or may be in the future, devoted. The cutting of a farm into two parts, separated by a railroad, involving permanent inconvenience, danger, and increased cost of improvements and of operation, interference with drainage, or with satisfactory sub-division, is an illustration of permanent damage. Temporary damages are such as entail the expenditure of money or cause temporary inconvenience and loss, but do not of themselves impair the present or future fair market value of the remaining property. The cost of moving a building located on the right of way to a new site where its value, convenience, and usefulness to the owner are not decreased, or the cost of removing or rebuilding fences and other improvements, are fair illustrations of temporary damages.

While these elements of market value, permanent and temporary damages, may not be itemized separately in the settlement or award, it is safe to say that they enter into the aggregate consideration paid for nearly every right of way acquired. The necessity for recognizing and distinguishing between them in some appraisals will appear subsequently in this discussion.

The fourth element, incidental expenses incurred in obtaining a right of way through a property, is as truly a part of the actual cost to the railroad as the nominal price paid to the owner. This would

seem to be such an obvious fact as to require no argument, and yet it has been denied or ignored in some Court decisions and in a number of appraisals of cost of reproduction. It includes such items as cost of conferences and negotiations, legal services, cost of condemnation proceedings, etc. Mr. Whinery.

The compensation or consideration paid for a right of way is determined either by mutual agreement or by the award of a theoretically disinterested body of men, on the evidence presented, in the judicial procedure known as condemnation. In case of settlement by mutual agreement between the railroad and the owner of the property, the amount of consideration may vary nominally from zero (donation) to any figure which the railroad may be willing to pay and the owner to accept. The compensation thus agreed on, however, cannot always be taken as a just measure of the cost or value of the property transferred. There may be other valid considerations, which may or may not be named in the deed, but, whatever they are, they do not affect the actual value and, generally, not the ultimate cost of the property to the railroad or its appraisal value for some purposes. This is true even where the right of way is donated. If one friend is good enough to donate to another $1 000 to be used in establishing a new business, and the money is thus used, it becomes, legally and morally, as truly a part of the latter's invested capital as the money supplied by himself. As a matter of fact, however, a donation of right of way is practically almost never a donation except in name. The so-called donor expects to, and usually does, in some way, get value received, and the railroad pays a price, usually in the form of supplying service for a time at a loss, due to the building and operating of its road in advance of the time when the developed business becomes sufficient to yield adequate returns. It may safely be asserted that in such mutual settlement a fair and proper consideration passes, directly or indirectly, between the grantee and grantor, and that the full value or ordinary cost of the donated right of way should be reckoned as a part of the money invested in the road.

On the other hand, if the railroad agrees or is compelled to pay an exorbitant price for the right of way, it must be assumed, unless fraud or gross misconduct can be shown, that the money so paid represents as truly a part of the legitimate and necessary cost of the road as though it had been expended for rails and cross-ties. This is true whether the sum paid was a reasonable price for the property or included excessive actual or alleged damages, or was consented to by the railroad to avoid delay or litigation. Where the right of way is secured by condemnation, the theory is, and the fact must be assumed, that the compensation awarded was determined by a body of competent and disinterested men after weighing all the facts,

Mr. Whinery. and that the sum awarded was fair and just, and is, therefore, a proper charge against the cost of the road and a like credit to its capital account.

An appraisal of the value of the physical property of a railroad may be undertaken for a number of purposes, among which may be named:

1. To ascertain the cost of the railroad for the purpose of determining the reasonableness of its capitalization;
2. To ascertain the value or cost of the railroad property as an element in the determination of proper and reasonable rates;
3. To determine the value of the property preliminary to a prospective purchase or sale of the railroad;
4. To ascertain the value of the railroad property for the purposes of taxation.

Confining the discussion to right of way and real estate, we may consider the principles and practice that should control in an appraisal for each of these purposes, or cases.

Case 1.—Appraisals to Determine the Reasonableness of Capitalization.—The word "capital" is variously defined. Applied to railroads, it is generally understood to mean the amount of outstanding evidences of cost or debt in the form of stock and bonds. The scientific as well as the ordinary and common-sense definition, however, is that capital is the amount of money permanently invested in a business, and the word is used in that sense in this discussion. It is a reasonable proposition that the evidences of indebtedness of an enterprise—stocks and bonds—should not much exceed the amount of money actually invested in the business, which, in the case of a railroad, may be defined as the amount of money expended originally in its organization, financing, construction, and equipment, plus the amounts since expended in additions and betterments, plus a reasonable amount of free money required for conducting the business, commonly called working capital; and the object of an appraisal, with reference to capitalization, is to determine whether such equality exists.

From this point of view, the question of capitalization is essentially one for the accountant rather than the appraiser. Under usual or normal conditions, neither the present reproduction cost nor the market value of the property can be relied on to disclose the amount of capital which has been actually and legitimately invested in the railroad. Thus, it is possible to conceive of two roads which, to-day, are identical in every respect. One of them, however, was built a generation ago and the other quite recently. When the first was built, the prices of construction work and equipment were materially lower than when the second was built, and the capitalization of the

latter will necessarily be correspondingly higher. It would be obviously unjust to assume, because their property now inventories the same, that the younger road is over-capitalized. Mr. Whinery.

The real question to be answered is: What amount of money has been, and, therefore, is now, actually invested in the property? In other words, it is a question of cost and not of present value. The principle is here stated in its broadest terms, and certain reservations must be kept in mind. The permanent destruction or abandonment of property, the payment of dividends out of capital or out of earnings necessary to maintain the property in normal condition, and other like practices which are, if not dishonest, violations of sound business principles, may impair the capital, and if found to exist, must be taken into consideration. On the other hand, the retirement of bonds by paying them off, though it may reduce the outstanding evidences of indebtedness, commonly called capitalization, does not decrease the actual capital or money invested in the road.

Unfortunately, correct and adequate accounts of expenditures chargeable to capital account from the beginning are usually not available. Either they are wholly absent for early periods, or are incomplete, or have not been kept in such a way as to distinguish clearly between betterments on the one hand and maintenance and operation on the other, and it is impossible to determine from them the true investment cost. The very common practice of charging extensive betterments to cost of operation or maintenance, which has prevailed to a large extent in the past, is a pertinent illustration of this condition.

In the absence of complete and trustworthy accounts, an appraisal of the property may be resorted to as the best way to ascertain an approximate estimate of the amount of money invested, or, in other words, the reasonable capitalization.

If the principles here laid down are sound, it must be obvious that an appraisal for this purpose should aim to disclose the actual cost of the property and not its present reproductive cost or marketable value. An inventory of existing property is, of course, necessary, but the unit prices applied to determine aggregate value should be those of original cost and cost of betterments at the time they were made. Neither depreciation nor appreciation of original values has any proper place in such an appraisal, unless it appears that the capital has been impaired by some of the actions or causes already mentioned.

The depreciation of the property by ordinary causes (excluding those named which obviously impair the capital) does not decrease the amount of money invested, nor does it ordinarily decrease the capacity of the property for rendering service, as long as the property is kept in reasonable operating repair. A locomotive, for instance, may be ten years

Mr. Whinery.

old, and yet be as capable of efficient and economical service for the work required of it as when it was new. Even when so worn out as to be incapable of satisfactory service, it will be replaced by a new one, which, if purchased at the same price as the old one, will neither increase nor decrease a properly kept capital account. Nor will any depreciated value assigned to it at any time affect the amount of money invested, on which interest and dividend charges must be paid.

On the other hand, any appreciation of the value of a property, by causes other than the actual investment of additional capital, does not affect the capital account. It is a so-called unearned increment which properly belongs in a surplus rather than a capital account. Nor should earning capacity represented by the market price of stocks or bonds be given any weight.

Applying these principles to the appraisal of right of way and real estate, it follows that the object should be to ascertain and use values which represent the actual cost of the property to the railroad. In such an estimate of the value of right of way all the elements which go to make up the total cost, fair market value, permanent and temporary damages, and incidental expenses, should be reckoned and included. Practically, this may ordinarily be accomplished most satisfactorily by applying a properly determined ratio or multiplier to the fair local market value of similar land at the time the property was acquired. Usually, sufficient records of actual cases will be available to establish, with reasonably close approximation, the value of the multiplier to be used. This matter will be considered more at length under Case 4.

Case 2.—An appraisal made for the purpose of establishing or regulating rates should be governed by the same general principles and methods as one made to determine the reasonableness of capitalization. In fact, their ultimate object and uses are substantially the same.

The lowest rates which a railroad may reasonably or legally be required to charge are such as will repay the total cost of the service rendered, including interest charges and a fair return on the money invested, as any lower rates would be confiscatory. Interest and dividends are a part of that total cost, and as they are functions of the capital invested, the latter must be known in order to determine legitimate cost and to frame proper rates.

This is the only logical theory on which an appraisal of physical property can be called for or utilized as a basis for regulating rates, and, therefore, an appraisal for this purpose should disclose the amount actually invested, as in Case 1. This applies to right of way and real estate as well as to other property.

It is true that enhanced value of real estate may increase the amount of taxes assessed against and collected from the railroad company; but, in the usual method of railroad accounting, taxes paid are treated

as an item of expense separate from and independent of interest and dividends, and do not, therefore, affect the capital account. Mr. Whinery.

Case 3.—An appraisal made for the purpose of determining the value of railroad property in a contemplated purchase or sale will necessarily differ in many respects from one made for the purposes named in Cases 1 and 2, and the character of the appraisal will vary with the nature and circumstances of the proposed transaction. When the proposed sale is by mutual agreement between parties equally disposed and free to deal, the appraisal is essentially equivalent to the ordinary invoice of industrial or commercial concerns. In other words, its purpose is, chiefly, to disclose market value. Such transactions are mostly between private parties, do not concern the public, and need not be considered here. But where a Government elects to acquire property by the exercise of its power of eminent domain or other coercive processes, regardless of the owner's desire or willingness to sell, the situation is wholly different. If the owner is to be deprived of his property, he is entitled to full and even liberal compensation therefor. This applies, not only to the naked value of the physical property, but to franchise rights and other intangible values, and to any special physical conditions which may make the property especially remunerative. For from any sound business standpoint, present and prospective earning capacity is more truly a measure of value than the cost of the property or its physical value, and is as much a real asset as physical value. Therefore, the guiding principle in an appraisal of the property should be to ascertain its present and prospective productive value, of which original cost or cost of production will be only one element.

The soundness of these views will hardly be questioned in the case of the property of any private person or corporation whose title to the property is clear, equitable, legal, and untainted by fraud. It does not matter when or how such a sound title was acquired, nor whether the property would be of equal, or in fact, of any, value to the purchaser.

In the case of railroads and other quasi-public corporations, created and existing under governmental permission or franchise, however, the title is clouded by stated or implied reservations embodied in the franchises, and this fact must be taken into consideration.

These franchise reservations, it is true, do not confer any rights to ownership or title. The right and power to expropriate the property of private owners without their consent are derived from a different and wholly independent source—the doctrine of eminent domain, which may be exercised in any case for the public good. The rights and powers of Government derived from franchise grants do not usually extend beyond a certain degree of control or regulation for the public good. It is claimed by the legislative, and affirmed by judicial,

Mr. Whinery. authority that the Government may intervene in the operation of a quasi-public corporation to the extent of requiring satisfactory service for reasonable charges; but the question, what are reasonable charges, is still an open one. In fact, it is one which is very difficult to decide, not only in a general way, but as to any particular case. It will be conceded by nearly all fair-minded people that, where the service is inadequate and rates are not only oppressive to the public but yield excessive profits to the owners, it is not only the right but the duty of the Government to intervene and to establish relations between the two which will be fair and just, with due regard to the rights of each. It seems to be widely held that reasonable charges are only such as will repay the cost of the service and yield a fair return on the capital actually invested; and fair return is defined to mean little if any more that the prevailing rate of interest. This theory does not recognize intangible property, such as productive value, and, if enforced, might greatly depreciate any value of the property based on its special earning capacity.

The combination, in the hands of the Government, of the franchise right to control, and the eminent domain power to expropriate, property, unless wisely administered, may be a very dangerous one. If a quasi-public enterprise may be forced to extend its service and reduce its rates to such an extent as to cripple its earning capacity and thus to reduce greatly its commercial value, and the Government may, later, seize or condemn the property at the reduced value created by its own acts, the result may be as truly confiscatory as if physical property were taken without compensation to the owner. It is true that the National Constitution prohibits the taking of private property without due compensation; but it is silent on the question as to what constitutes due compensation. This question must be answered ultimately by the Courts. Thus far it has not been answered conclusively and fully as to the intangible values of quasi-public corporations; and until it shall be so answered, the question of a proper appraisal of such properties for the purpose of an enforced sale cannot be decided definitely. There are hopeful indications that the broad ground may be taken and sustained that productive value, in whatever form it may be found, whether physical or intangible, shall be given proper consideration in such appraisals.

In the present unsettled condition of many questions of detail, it is most important that an appraisal of this character should be thoroughly and intelligently considered by the authority ordering it, and that definite instructions as to the principles which shall control it be given to the appraiser, who must then be wholly governed thereby.

Assuming that the owner is entitled to compensation on the basis of a reasonable regard for the productive value or earning capacity of his property, as well as for its physical value, the general prin-

ciples outlined apply with special force to the appraisal of right of way. Mr. Whinery

While a country is new and unimproved, a right of way may have been acquired at a very small cost. Not only was the market value of the land very low, but the conditions were such that both temporary and permanent damages were almost negligible; but, to secure an equally good right of way through the same locality after the lapse of 15 or 20 years, when the country has become thickly settled and costly improvements have been made, would be a difficult matter involving great cost. Not only will the market value of the naked land have greatly increased, but numerous and costly improvements will be encountered which will warrant heavy damages. In such a case it would be fair to say that, other things being equal, the old existing right of way is physically worth what a new one in the same vicinity would cost. In addition to this physical value, the existing right of way may possess strategical advantages and facilities for doing business which it would be impossible for the new one to acquire, and, if so, due consideration should be given to the value of these elements.

There are no present indications that either the National or the State Governments seriously contemplate the purchase of the railroads. Nevertheless, it is well to call early attention to the fact that an appraisal for some other purpose, as for regulating rates, cannot justly be used for determining values in expropriation of the properties.

Case 4.—Where the object of an appraisal is to determine the value of railroad property for the purpose of assessing ordinary taxes, the principles and practice appropriate will differ materially from those applying to the other cases considered. This is especially true with regard to right-of-way land. Unless otherwise provided by State statutes, railway land is subject to the same rate of taxation as other lands, and the amount of taxes assessed depends on the valuation placed on the land by the assessors. This assessed value of land may not be, and in fact usually is not, the same as the market value. The ratio between the two values, however, is presumed to be applied to all lands alike. In other words, the assessed value for taxation is relative rather than actual. An appraisal of right-of-way land for taxation purposes, therefore, should be based on the assessed valuation of similar land adjoining it or in its vicinity. This does not mean, however, that it should be valued at the same unit price as such adjoining land, but rather that its actual value, when determined, should be multiplied by the ratio between the actual and assessed values which may be found to prevail in the locality. In determining value for taxation, the Courts have generally made it plain that

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neither the use made of, nor the amount of benefit or profit derived from, the land may be considered.

The question to be decided is, therefore: What is the value, other things being equal, of right-of-way land as compared with that of other land in its vicinity?

In seeking a general answer to this question, it may simplify the discussion to use for illustration a hypothetical case which is fairly typical of a majority of right-of-way transactions.

A owns a farm of 160 acres, the fair and reasonable market value of which, as a whole, and of similar land in the vicinity, is adjudged to be $50 per acre. For simplicity, it will be assumed that it is taxed on this full value. Through this farm a new railroad must secure a right of way, 100 ft. wide, requiring, say, 6 acres. The conditions are such that the three elements, fair market value, permanent damages, and temporary damages, are involved. It will be assumed that the parties cannot agree on the amount of compensation to be paid by the railroad, and that the right of way is condemned by a commission of disinterested, competent, and fair-minded men, who exercise their best judgment, after informing themselves of all the facts. They find and report that the market value of the land is $60 per acre, that the permanent damage is $600, and that the temporary damage is $140, making in all, $1 100. The question at once arises, why do they estimate the value of the 6 acres taken, at a higher price per acre than the admitted fair price for the whole farm; and is that action justified? It may be replied, that though it may be true that the severed land is intrinsically no more valuable than that which remains, common business customs sanction the higher valuation. The general analogy to wholesale and retail transactions may be instanced; also the familiar fact that when a tract of land is purchased *en bloc* and divided into smaller tracts or lots, these latter command a higher unit price than was paid for the whole tract. Again, fair market price is said to be that price established when both seller and buyer are equally free and disposed to deal. Now, if for any reason, B wanted to buy a selected part of A's farm, which is intrinsically worth no more than any other part of the farm, and is located so that its severance would not damage the remainder, it is natural and reasonable that A should ask, and B should be willing to pay, a higher unit price than A would ask for the farm as a whole. It is equally reasonable that the land severed for the right of way should command a higher price than the farm as a whole. What that higher price should be is a matter of judgment, and it must be assumed that the commission exercised its best judgment in the matter. It must be assumed that its award for permanent and temporary damages is also fair and equitable.

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The transaction being closed in accordance with the award, the question in due time will arise, how shall the properties be assessed for taxation? Here, the State becomes an interested party, and her rights must be taken into account. The permanent damage of $600 was awarded on the ground that the remainder of A's farm is permanently injured and, therefore, that its value is decreased by that sum. When the tax assessor appears, A may reasonably claim that that sum shall be deducted from what his farm would otherwise be assessed for. The assessor accedes to what seems a just demand, and appraises the remaining 154 acres at $46.10 per acre, and proceeds to appraise the railroad right of way. Here some perplexing questions arise. He may readily decide that the property should be appraised on the value fixed by the Commission, but he discovers that even when this is done, the aggregate assessment on the whole of the property will fall short of the amount the undivided property has been previously appraised at by $540.60. In other words, that on such an appraisal, the State will lose the taxes on that sum. This would obviously be unjust to the State. Further study shows him that in order that the State shall receive the same amount of taxes as before, the permanent damages deducted from A's appraisal must be practically all added to what would otherwise be the appraised value of the right of way. In other words, permanent damages must be considered as accruing to the benefit and value of the severed land, in addition to what would otherwise be its fair market value. He, therefore, lists the right of way at $\$360 + \$600 = \$960$, or at the rate of $160 per acre, and, under these appraisals, the State will receive substantially the same amount of taxes as heretofore. The value per acre thus ascertained is $3\frac{1}{2}$ times that of other land in the vicinity.

The ordinary tax assessor may not enter into such nice reasoning or computation, or reach a like result, but he might well do so, and the soundness of the argument, from the State's point of view, must be conceded.

The conditions described relate to a time closely following the acquirement of the right of way. The question arises whether the conditions then found continue into the future, say, 20 years thereafter. The market value of surrounding land may have increased or decreased in the meantime, and the naked value of the right-of-way land may have increased or decreased accordingly. The award for permanent damages, however, does not change with time. The injuries to the remaining land, from their very nature, must be regarded as permanent and continuous, and their value must still inhere in the right-of-way land. It is, therefore, still a factor to be reckoned with in appraising the property for taxation purposes.

Coming now to the application of these general principles, it would

Mr. Whinery. appear that a proper appraisal of right-of-way land for taxation purposes should be based on at least three elements of value:

First. The fair market value of similar land in the immediate vicinity (excluding, however, adjoining land permanently damaged);

Second. A reasonable percentage to be added for increased value due to selection and severance;

Third. The amount of the permanent damages caused by the taking of the right of way.

If in any given case the records of the original transaction were available and the compensation paid were properly itemized, it would not be difficult to arrive at a proper valuation; but, in practice, especially in the case of the older railroads, these data are hardly ever available, and the appraiser must exercise his best judgment, particularly as to the fair amount of the permanent damages.

In fact, it is found in practice that it is hardly practicable or even possible to consider each individual tract of a right of way thus in detail, and that it is necessary and desirable to formulate some general rule to be applied to the determination of the value of right-of-way land, either as a whole or to certain classes or local sections. This is the more permissible because the right-of-way land of any railroad is likely to be assessed as a whole, and a correctly framed scale of values is likely to give fair average results.

The simplest and, perhaps, on the whole, the best procedure is to assume that the value of the right-of-way land bears some fixed relation to the market value of other lands in its vicinity, and to apply some fixed multiplier of that market value to the right of way. Multipliers varying from one to three have been used in different appraisals, where the purpose of the appraisal has not been clearly defined.

The author states that it is a well-known fact that land for right of way usually costs from 2 to $2\frac{1}{2}$ times as much as the market value of surrounding land. From the writer's experience (not, however, very recent), in well-developed farming country, he would say that these figures are very conservative, and that factors of from $2\frac{1}{2}$ to $3\frac{1}{2}$ would be more nearly correct; perhaps, $2\frac{1}{2}$ would be a low average figure.

It would not be fair, however, to use this factor of cost as a multiplier for determining values for taxation, for it includes the elements of temporary damages and incidental expenses which, obviously, should be excluded from an appraisal for taxation. If we assume that these amount to one-fifth of the total cost, the proper multiplier would be 2, and we would have the general rule that for taxation purposes, right-of-way land should be appraised at double the value of other land in its vicinity.

In the writer's opinion, it will seldom be found that a proper multiplier, determined in accordance with the principles here outlined, will fall below that figure. Mr. Whinery.

It may be, and generally is, claimed by railroad men that the prices thus commonly exacted and paid for right-of-way land are excessive, and that such differences in value are factitious. The fact, however, that they have prevailed for half a century and over the whole country, whether the right of way has been secured by private purchase or by condemnation, would seem to indicate that the general ratio has a substantial foundation in fact.

The author refers to the fact that in the recent re-valuation of the railroads of New Jersey, where the purpose was avowedly to establish a basis for taxation, right-of-way land was appraised by the expert of the State Board of Appraisers at the same unit value as adjoining lands. The writer cannot but believe that if this appraisal shall be finally adopted as the basis for taxing that part of the railroad property, the State will fail to receive the amount of taxes to which it is justly entitled. The land (first-class) was appraised at nearly $47 000 000, but this embraced land for terminals, etc., the separate value of which is not given. Assuming that two-thirds of the whole was properly classifiable as right of way, which should rightly have been appraised at double the value of adjoining land, the State would lose, annually, taxes justly due it on somewhat more than $30 000 000 worth of property.

It is not asserted, of course, that the principles herein advocated will be applicable to every case for which an appraisal is called. Even in the absence of definite instructions calling for a different treatment, a great variety of conditions and circumstances may develop, which may require modified action in individual cases or classes of cases.

The writer's object has been to outline the general principles which, in his opinion, should underlie and control appraisals of this kind of railroad property.

F. Lavis, M. Am. Soc. C. E.—Mr. Wilgus is to be congratulated on the very clear and concise presentation he has made of the basic principles governing the valuation of railroads. He has covered the ground so thoroughly as to leave little opportunity for discussion, and, although the speaker can do little but concur with him, it is, perhaps, not inappropriate, in view of the present-day interest in this subject, to express this, and emphasize, if possible, some of the more important points that are made. Mr. Lavis.

In a discussion of the paper* on this subject by Henry Earle Riggs, M. Am. Soc. C. E., the speaker pointed out some reasons why valuations of the railroads might not be an unmixed evil, as seemed to

* *Transactions*, Am. Soc. C. E., Vol. LXXII, p. 174.

Mr. Lavis. be generally assumed at that time, the conclusion of that discussion being as follows:

"First, that valuations properly made may be the means whereby confidence may be restored, not only in the mind of the general public, but in that of the investor; but, in order to obtain this result, the railroads should urge, with all the power they possess, the necessity of having such valuations made by a body of men, some of whom, at least, should be engineers, big enough to entitle their opinions to the respect of both sides, and thoroughly qualified by training and experience for the work.

"Second, that, as far as possible, regulation should be general or national, so as to avoid the complication of dividing all roads at the State lines, and of having different regulations in different States.

"Third, that there need not necessarily be any relation between rate regulation and rate-making. Rate regulation can well be confined to rates in the aggregate, rate-making applies to the adjustment of individual rates, and must necessarily be the work of men well versed in all the varied elements which control it and the particular conditions affecting the business of each particular road."

The paper by Mr. Riggs was an able discussion of methods of obtaining the cost of reproduction, but the author refused to recognize that the consideration of the so-called "intangible values" had any place in a physical valuation, and he did not consider that the purpose for which an appraisal was to be made should have any influence in determining the value of the property.

It is the discussion of these particular points by Mr. Wilgus which the speaker believes should be emphasized. He points out distinctly that the reason for making the valuation, or the purpose for which it is to be used, has an important bearing on the method of making it, and also states the principles which should guide an experienced man in making a reasonable estimate of at least some of the so-called "intangible values," or perhaps it would be better to say that he has outlined so completely the really tangible values as to have eliminated all or nearly all which can be called intangible, which are included in the unbreakable circle of argument in which it is claimed that the rates are based on values and the values on the rates.

It is shown in the first place how the appraisal of the individual items composing a railroad, without relation to their value as correlated parts of a whole, may be justified for taxation purposes, but is not a proper method for determining the value of the property as a living entity, that the "original cost to date" method is untenable on account of the almost universal lack of records of any value and for other reasons, and the conclusion is that the "Cost of Reproduction New" is the only method whereby an appraisal can be made which will be fair and just to both railroads and public, and which will give a fair value to the property as a whole and as a railroad, if it be properly made.

Leaving aside the question of taxation, which is really a local issue, the valuation of the railroads is now to be made by the Interstate Commerce Commission principally in order to determine whether the capitalization is fair, whether the rates now being earned give a fair return on that capitalization, or as information on which it may base its judgment in regard to new capital requirements. To one with experience in other countries, where the regulation of the railroads is most jealously guarded by the Government and where it does not act either as a serious deterrent to development or serious inconvenience, this does not appear altogether undesirable or unreasonable, but, whatever one may think about this, it is begging the question to say that no valuation will give adequate values for these purposes. What we have to do is to admit that valuations are to be made practically and solely on this account, and determine how they may be made properly. Mr. Lavis.

The application of any valuation of a railroad property to the adjustment of rates is, of course, complicated, and it can easily be imagined that, on first consideration by any one at all familiar with the intricacies of rate-making, the difficulties appear insurmountable. Suppose fair valuations are arrived at; suppose a fair return on this value is fixed, and the aggregate of the rates raised or lowered by a certain percentage to give this assumed fair return; how, it is asked, are the differences in management and the thousand and one other inherent differences in physical characteristics and conditions to be overcome? There would be no competent answer to this were each railroad to be taken as a unit or an attempt made to regulate individual rates, but, inasmuch as it would be difficult to change a rate on, say, the Pennsylvania between New York and Chicago without making a similar change on the Baltimore and Ohio, Erie, New York Central, etc., it seems impossible to use such valuations as may be arrived at for any other purpose than the regulation of the rates as a whole over a distinct section. That such a method of rate regulation is a practical one has already been recognized by the Committee of Presidents of the Eastern Railroads. For some time that Committee has endeavored to obtain permission to raise certain individual rates which were admittedly too low, but the opposition from the shippers has prevented favorable action by the Interstate Commerce Commission. The Committee, therefore, has now decided to ask for a blanket increase of a certain percentage on all rates throughout the Eastern territory, as there seems to be far less objection to the rates, *per se*, than to any change in the relation of certain individual rates to certain others, and this is quite in line with the speaker's conclusion in his discussion of Mr. Riggs' paper.

The trend of practical endeavor, therefore, as well as a common-sense view, seems to lead to the conclusion that the only adjustment

Mr. Lavis. of rates can be a blanket one, covering a large section of the country where prevailing conditions are generally similar, and to the speaker this seems to put the question of valuation on a basis where many of the objections, which may be and are quite properly raised, against valuation of separate roads or parts of them, can be overcome.

Most of the arguments against any theory of basing rates on valuation are founded on the inherent differences in physical characteristics, methods of management, local conditions, etc. In an address delivered before the Southern Commercial Congress, in April, 1911, by Charles Hansel, M. Am. Soc. C. E., it was shown that a higher or lower rate of gradient on two or more competing lines might materially affect their value. He assumed three lines, each 100 miles in length, the first with 0.3% grades, the second with 1.0% grades, and the third with 1.136% grades, and showed that for a tonnage of 10 000 per annum the capitalized value of the additional cost of hauling the tonnage on the two latter might amount to some eight or ten millions of dollars.

Of course, the assumption of two roads between the same termini with essentially different physical characteristics is the *reductio ad absurdum* argument. As a matter of fact, when there are two or more roads between the same termini, or which reach the same points, the rate between these points for the same class of commodity is the same, no matter what the operating conditions of the properties are. If the valuation of the property is for the purpose of purchase or sale, the operating value, as affected by the physical conditions or physical characteristics, should be considered, but, if the valuation is used as a basis for fixing rates between competitive points, it cannot be.

Such a case as that cited above is, from a practical standpoint, purely theoretical, and it may be admitted at once that, if there were any two such roads, no valuation would be a fair basis for fixing the rates on them. If the rates were fair for one, they would be likely to be unfair for the other; looking at the matter broadly, however, there can be no more reason in the valuations to be made by the Interstate Commerce Commission for comparing physical conditions or physical characteristics of competing lines than there is now. No two lines could be more dissimilar than the Pennsylvania and the New York Central between New York and Chicago, and yet the rates are the same. If the Erie Railroad spends a large sum of money and makes improvements which will reduce its ruling grade to, say, 0.3%, it can hardly be expected that on that account it will be compelled to adopt a lower rate than it charged before, because it can operate more cheaply, or charge a higher one because it has spent a lot of money.

There is, perhaps, a certain class of individual rates between local points which are, and probably will continue to be, subject to in-

vestigation by the Interstate Commerce Commission or the State Boards. The regulation of these rates, if necessary, must inevitably be based very largely on the cost of service, and, as a basis for determining this, or at least as a starting point, there would seem to be nothing better than an adequate appreciation of the value of the property involved. It seems improbable though that there could ever be considered even, the proposition to fix rates separately on, for example, the Pennsylvania, the Baltimore and Ohio, the Erie, and the New York Central on the basis of the valuation of the individual properties, or even a combination of the values of the physical properties with the capitalization and earnings of each individual property; but that need not prevent the use of a fair valuation taken together with an appreciation of the cost of operation, as a basis for a general advance of rates which might be shown to be necessary in order to provide a fair return to the stockholders and an inducement for the provision of necessary new capital. Mr. Lavis.

It seems to the speaker to be entirely outside the realms of practical discussion to consider for a moment the actual costs of any of the parts which go to make up the railroad as a whole, except as such costs might be a sidelight on their value to-day, or we would never get anywhere. Take, for instance, right of way: some of it may have been given free; it may have been paid for at ten times its value; it may have been obtained by right of eminent domain and the legal expenses charged to something else. Rails were bought at $20 or $40 a ton which would now cost $30. A tunnel was built at a cost to the railroad by which the contractor lost money; another at a cost which allowed a good profit. The whole road may have been bought at a foreclosure sale and so on, almost without end.

The speaker was asked some little time ago to prepare a basis for the determination of unit prices to be used in connection with the valuation of a certain railroad. In looking up actual costs of rock excavation to this road, many contracts were examined dating from 1880 to the present time, the prices ranged from 65 cents to $2.50 per cu. yd., and all within a comparatively narrow range of territory. This, of course, is nothing new, but surely no one with any experience could expect to base the value of the rock excavation on, say, the Erie Railroad as it exists to-day, on such original costs of parts of it as might be found by an examination of the records. There are altogether too many complications to make it possible to consider original costs, except such as those in which all the governing factors are known which may be used as a guide in determining present-day values. A rock cut may have been taken out originally at $1 per cu. yd., and a slice taken off the side for another track might easily have cost $2, or even under certain conditions less than it did in the

Mr. Lavis. first place. It seems to the speaker that, looking at the matter from a practical standpoint, these and innumerable other complications of a similar nature cannot be considered now. We can only consider what it would cost to take that cut out if we had to do it to-day and get it in the shape it now is, and that is quite within the range of the ability of practical men. Really, the cost of reproduction new is the only logical, practical way that will give results which, at least, will be as fair to one road as to another, and as fair to the public as to the railroads.

In many countries where the Government has retained full control over transportation enterprises (and, after all, if at all fairly exercised, this is far better than either unbridled private enterprise or Government ownership), the amount of the capitalization which will be recognized by the Government is definitely fixed. The first cost is determined and approved during and on the completion of the construction, after a satisfactory investigation of the books, and additions made yearly to cover the additional capital expenditures. In the United States, for many good and sufficient reasons, and others equally bad and insufficient, we have let the railroads alone, and now the Government is trying to regain the control it should never have relinquished. As long as this control is fairly exercised, we shall be all right. To exercise it fairly, those charged with it must have knowledge, and one of the things they should know is the value of the property they are controlling.

This value can be obtained fairly, but, it seems to the speaker, only by putting everything on a common basis. There can be no fooling with such questions as "right of way has no value because it has been given to the railroad," or that it "has not increased in value," or that "if we wanted to reproduce it to-day we would not pay a farmer three or four times the acreage value if we cut through between his homestead and the rest of his land." Such speculations as these open up vast vistas of discussion to which there is no end. The "Cost of Reproduction New" is entirely practical and one well within the range of the understanding of any fairly intelligent person. To obtain it fairly needs practical experience, training, and a knowledge of railroad conditions, and Mr. Wilgus has done a service in calling attention to some of the matters which, if the work is to be done properly, must receive most careful consideration from those who he truly says are "burdened with a Herculean task" in undertaking to value all the railroads of the country.

The necessity for the employment of competent men is pointed out, and this fact should be emphasized, for though it may be generally admitted that a certain number of competent engineers are required, it is not always conceded that railroad as well as engineering ex-

perience is required in many of the comparatively minor, or at least intermediate, positions. Mr. Lavis.

Even the first step, the compilation of an accurate inventory of the property of a railroad, must be taken by men in the field who have become capable by long association with railroads in the making and in their subsequent maintenance. Take, for instance, the one item of the earthwork on a railroad, the questions of settlement of embankments built across marshes, the settlement of the embankments themselves, the estimation of slides, the classification of the material, haul, the general seasoning of the whole roadbed, etc., cannot be properly answered or values estimated by any but men of experience who can and do judge the conditions on the ground. The task of making an inventory and fixing prices of the measurable items, although one of great importance, is well within the range of an organization which can be developed from the large number of competent engineers available who have had fairly long and wide experience in railroad construction.

The really important matters pointed out by Mr. Wilgus, however, are the estimation of the value of the two stages of the development of a railroad preceding and succeeding the actual construction period, and the speaker believes, with him, that an equitable valuation of the costs to a railroad during these two periods is not an impossible or impractical task, and, if fairly made by men of widest experience in railroad affairs—not merely engineers with only construction experience—will largely cover the so-called "intangible values."

Until very recently the speaker thought that the position taken by Mr. Wilgus, and as expounded in this paper, was so obvious that there could be little chance for argument, but there still appears to be a large number of otherwise intelligent people who continue to think that the valuation of railroads is necessarily different from the valuation of any other business property, in other words, that the valuations to be made are to be simply an inventory of ties, rails, locomotives, etc., with a price for each, and that the "good will," etc., is to be ignored. We have, perhaps, rather ignored the discussion of the "intangible values," because we have not been able to see quite clearly how we were going to estimate their value, but that may be due to the same state of mind we are often in, when approaching any problem of importance which may come up. We may have a bridge, or tunnel, or anything else, to design and construct. When we start we may not know exactly how it is going to turn out, even though we know we can do it; we know there are difficulties; we know that the first tentative designs will be all changed; but we also know that if we keep at it long enough and with a sufficient degree of intelligence, backed by experience, we shall work it out. It seems to the speaker to be the same way about valuation. Proper consideration will show

Mr. Lavis. that many of the so-called intangible values have considerable substance, and a fair determination of their worth can be arrived at by a proper process of intelligent application. Mr. Wilgus has drawn a broad outline of the matters to be considered; it is for those who have the work to do to fill in the details.

There might be endless discussion, of course, in regard to what these values should be, but it looks as if we had come to the point where some one will have to decide. It is not a question of absolute right, but of coming to a decision which will be as fair as possible to all concerned. There is nothing impractical in this, the absolute right of the majority of disputes is seldom reached, most decisions are compromises or, at least, the best judgment of some man or body of men, and it is usually only necessary that we be assured of the competence and impartiality of the tribunal to permit us to acquiesce in the decision. It is necessary, however, that we be assured of the competence as well as the impartiality, and that all pertinent matters will receive due consideration. The necessity of this latter should perhaps be emphasized most particularly in connection with the estimation of the costs or value of those items which exist but are not easily or physically measurable.

Mr. Crehore. William W. Crehore, M. Am. Soc. C. E.—This admirable paper shows the author to be thoroughly familiar with his subject, which he treats in a comprehensive and exhaustive manner not to be expected from any other than a railroad official of wide experience. On some of the special points, however, which are matters of opinion only, a layman may be permitted, perhaps, to differ from the author's conclusions without exposing himself to the charge of presumptuousness. On this basis, the speaker wishes to take one exception to the opinions advanced in the paper.

In enunciating the basic principles of procedure and the several ways of determining the physical value, Mr. Wilgus refers to the method known as "Cost of Reproduction, Less Depreciation," and states that, for rate-making purposes, it seems to him that the physical depreciation should not be deducted from the cost of reproduction new. His reasons for this are "that all expenditures for renewals and repairs should be charged to working expenses, and not to capital," and that "normal depreciation is not to be treated as a wastage of capital, but as an element in the cost of operation that is covered by the rate." He then goes on to state that the law requiring "that valuations shall be revised from time to time as improvements and other changes are made, in effect prohibits the deduction of depreciation, as otherwise the constant addition of amounts expended in the replacement or renewal of items that had been included in the valuation at their depreciated price, would be a violation of the rule of the Interstate

Commerce Commission that operating expenses should not be charged to capital." Mr. Crehore.

The fact should not be lost sight of that betterments and improvements, when paid for out of income, are just as much property as if paid for out of capital, and, as assets of the company, they should be included in the inventories made from time to time. It is the evident intention of the Interstate Commerce Commission to draw a definite and distinct line between funds used for extension and enhancement of railroad property, and those used for the prevention of undue depreciation of existing property; in other words the distinction is between repairs and renewals necessary to maintain the original investment at its full efficiency, on the one hand, and such betterments and improvements, on the other hand, as constitute permanent additions to the original investment. In order to protect the stockholder the property paid for by his original investment should be kept up by repairs and renewals as nearly as practicable to 100% efficiency, or a fund should be established to reimburse him for the difference.

It is customary to look at depreciation as a stockholder's liability, but, in truth, it is his liability only because he has received in dividends at some previous period the money which should have been expended to keep the property up to 100% efficiency, or which should have been put into a fund to be used for that purpose. It is unquestionably the moral duty of the management to keep the company's property up to its full efficiency, or to establish out of the income an equivalent reserve fund. When this is done, there can be no liability for depreciation on the part of the stockholder. Whenever this money is paid to him as dividends, however, instead of being put into the property, he is then actually receiving back part of his original investment, on the instalment plan, as it were. If, then, the stockholder has received this part of his investment back, it certainly remains no longer among the assets of the corporation; hence, to obtain a proper value of the assets, for rate-making purposes, or for any other purpose, the amount of this depreciation should be deducted. The opponents of this view certainly will not contend that rates should be made proportionate to assets which do not exist in the corporation.

The author's view that depreciation should not be deducted is based on the stockholder's liability to be called on at some future time for fresh capital to put the property back to 100% efficiency. Until that time comes, however, and the stockholder does thus put his money back into the property, is there any reason why the rates should be large enough to pay him dividends on that portion of his investment which he withdrew from the corporation, as well as on that which he still has in it? Or if, as is usually done, the property is put back to full efficiency by the use of future income (that is, through an issue of bonds), is there any good reason why the stockholder should be the sole bene-

Mr. Crehore.

ficiary from that operation which has cost him nothing? Does it, in the first place, seem just to make the public pay rates high enough to cover dividends on the depreciation of the property, when the equivalent of that depreciation has already been paid back to the stockholder? In the second place, is it just and right that the rates should be high enough to cover dividends on the original value of the property including depreciation, and, at the same time, high enough to retire an issue of bonds necessitated only because of the withdrawal of the deprecation reserve fund by the stockholders?

To make the rates high enough to cover future betterments and improvements and to lay the money aside for this purpose is one thing; but to make such rates and then devote the money thus raised to dividends based on the original value of depreciated property cannot be justified. The stockholders should not expect to "have their cake and eat it too." To argue that this is customary does not justify it as good practice, nor does it appeal to the fair-minded gentlemen composing the Interstate Commerce Commission as being either good theory or good practice. Any corporation which is handled so as to allow its property to depreciate without providing a fund out of the income as the equivalent of this depreciation, cannot claim that the full investment of the stockholders is represented in the assets of the corporation, and, therefore, cannot expect to be allowed a rate based on fictitious property just because it has been capitalized.

The market value of any property other than a public utility, that is, any property unregulated by law, is a direct function of its income, fluctuating with the income. This market value apparently is unrelated either to the intrinsic value of the company's assets or to the amount of capital invested. Investors look only at the rate of income and the safety of the investment. If, for instance, the stock of a reliable concern pays 40%, this stock cannot be bought at par; but the market price will be well up to a point where dividends on it will be normal.

Now the difference between this market value of the "going" concern and the actual intrinsic value of its real assets is ascribed to the "good-will" of the business, or the "franchise" value, as it may be called in the case of a public utility, meaning thereby the value of its intangible assets. If the business is highly prosperous, the good-will or franchise value is correspondingly great. The actual intrinsic value of a going concern's real assets does not change merely because of the advent of prosperity or the reverse, but the good-will or franchise value does vary for this cause. With some very highly developed monopolies, the good-will value of the business is the largest asset, the intrinsic value of its property being merely incidental.

This being so, it is evident that the problem before the Interstate Commerce Commission, in regard to railroads, is to reverse the natural

operation of an unrestricted monopoly. Instead of "charging all the traffic will bear" and determining the good-will value of the business by the amount of income, as is common with a private corporation, the Commission's problem is to ascertain the value of the assets (intangible as well as tangible), and then to make the income conform with it by virtue of the rate-making power. This difference between a public utility and a private corporation seems generally to be unrecognized. In the working out of this problem there is very little to be learned from the example of private monopolies, excepting as they may be said to teach "how not to do it". In the Commission's problem it is necessary to prevent all exaggeration in respect to the good-will or franchise value in determining the value of a railroad's assets. Mr. Crehore.

A railroad is a monopoly created by the law-making power primarily for public uses. A private corporation, on the other hand, is created primarily to make money for its stockholders. A railroad's charter is granted by a special agreement with the Legislature, and gives it an exclusive monopoly in its own territory, except at and near the terminals. Such a monopoly must of necessity be regulated by some common authority, in order that the communities through which it operates shall not be discriminated against in comparison with those similarly situated on other railroads, and for the further reason that the railroads are practically indispensable to all business interests. Each year sees the business of the country more and more dependent on the railroads for the interchange of commodities.

For these reasons, also, it is necessary that the public authority in control of the railroads should endeavor to have the rates fixed as low as is consistent with the value of the capitalist's investment. This investment, however, certainly does not comprise betterments and improvements which have been paid for exclusively out of rates (which, for this reason, are excessive rates) charged to the public. In this respect a railroad's opportunities to make money for its stockholders are far greater than those of a private corporation competing for a livelihood; and railroad investors have so long been accustomed to the advantage they possess for making the public pay for anything they want, that it will not be an easy matter to attract them when these opportunities are removed, although the return on their actual investment should still remain as good as, or better than, that of corporations in private business.

Neglect to provide depreciation funds is in the same category, both financially and economically, with the omission to establish sinking funds for outstanding bond issues. Both practices have brought about an enormous inflation of values by the introduction of fictitious capitalization. Bonds have been left outstanding long after the prop-

Mr. Crehore. erty or equipment purchased with their proceeds has become useless; or, if refunded, the effect is the same, because stockholders claim their share of the earnings beyond the lifetime of the property to produce which their proceeds were applied. Whenever an issue of bonds is refunded, which ought to have been paid off by a provision out of the earnings, its claim is added to that of the new bond issue for a share of the future earnings. Such bonds as are not co-terminous with the life of the property originally purchased with their proceeds, serve to increase the burden of inflation, because the security that was once behind them is abandoned, useless, or obsolete. To provide income for bonds like these is to carry a fictitious investment on the books, and with every refunding of debts that ought to be retired, the load of over-capitalization receives a new increment.

It has come to be the popular conception that to capitalize anything is to provide an income for it. But capital is wealth; therefore, when an income is provided for something which does not exist, there results a form of capitalization which adds no wealth to the property at all, but is fictitious capitalization or over-capitalization. It provides an income for fictitious investment. Property which has become obsolete or superseded by other property ceases to have any earning power, and is no longer entitled to any income. Hence the bonds, from the proceeds of which it was originally purchased, must be retired by the earnings of the period covered by the life of the property in order to prevent over-capitalization or inflation.

An exact compliance with this theory is, of course, not possible in practice. With the railroads of the United States, progress and development have caused such unforeseen changes in recent years that it has not always been possible to arrange bond issues which should terminate with the life of the property represented by them; but there could have been, and should now be, made a more vigorous effort to retire such issues as have outlived their usefulness, by payments out of the earnings rather than by refunding, and it must not be expected that the public will permit rates to be increased in order to enable the railroads to make a readjustment which has been necessitated by excessive rewards to stockholders. The stockholders have "eaten their cake" and that of the bondholders too, and their efforts to get the public to feed the bondholders no longer deceive the majority of those interested.

The great incentive behind this movement for the valuation of existing railroad property evidently lies in a desire to have more complete and definite knowledge as to the size of this load of over-capitalization carried by the railroads. The extent to which progress and development have contributed item after item to the load of over-capitalization in recent years is not realized by many; and the infla-

tion itself is totally denied by others. Naturally, there will be some among the latter who will be strongly impelled to complicate the valuation work, and to seek out every possible pretext for making the assets, both tangible and intangible, look as big as possible. It should not be inferred from this statement that Mr. Wilgus is credited with any but perfectly sincere and honorable motives in his elucidation of the subject. Mr. Crehore.

Throughout the paper he has repeatedly stated that the method of obtaining the physical valuation should be chosen with reference to the purpose for which the valuation is made; that is, for purposes of rate-making he would recommend a method giving a different result from that obtained by the method he would recommend for the purpose of selling the property. Perhaps still another method might be recommended for purposes of taxation. Much has been said recently about the increasing burden of taxation on railroad properties, and there is no doubt a tendency on the part of local authorities all over the country to assess railroad property more nearly at its true value than has been customary in years gone by.

Without in any way begging the question of physical valuation, the speaker takes the ground that the easiest and simplest way out of a complex and difficult situation, and one that would wipe out an immense amount of inflation, would be to order each railroad to put its own value on its property of all kinds, and to have it understood that the same value would be used in assessment for taxation as well as for acquisition of the property or for any other purpose. In other words, if there was any inclination to place a low valuation on the property for purposes of taxation, this would be counteracted by the knowledge that the Government would use that set valuation for rate-making purposes and for acquisition if desirable. With the aggregate of all these self-imposed railroad values thus put before it, the Interstate Commerce Commission could then determine fair and equitable rates based on these valuations. At least, if the rates thus determined were not fair and equitable, the railroad companies could not complain of the valuations on which they were based.

Our whole system of direct taxation is cumbersome, discriminatory, and unjust, putting a premium on shiftlessness. The man who keeps his property in good repair, his buildings and fences in order and well painted, is assessed far above his neighbor whose acreage is the same, but whose buildings and fences are dilapidated and broken down. If the estimate of each was accepted as the value of his own property, and if such valuation was registered in the public records to be used for all purposes, including taxation, the authorities would be relieved of a vast amount of burdensome detail, and if any injustice were done, the victim of it would have only himself to blame.

Mr. Crebore.

It is a poor rule that does not work both ways. What a boon such a system would be to the railroads for purposes of acquiring rights of way for extensions! Condemnation proceedings could be avoided, untold agents' commissions could be left out of consideration, and, best of all, an exact estimate of the cost of any proposed right of way could be obtained in advance merely by consulting the registered values of the property which it was desired to condemn. If the law authorized the condemnation, then the owner of the property would be obliged also by law to sell at his own registered figure. If property owners were permitted to change their valuations as often as once a year on a date fixed by law, and, when they failed to alter them, if the last previous valuation should be held to be valid until a new one was submitted on the regular date fixed for the purpose, speculation would be beneficially regulated rather than checked, and to the extent of the variation in taxation the State would share in the speculation, which is as it should be.

Under a general system of this kind applicable to all corporations and individuals alike, the unearned increment on unproductive but well-located property would be automatically and largely diminished. In any event, the full import of this feature would be shared by the State, and any tendency to exaggerate it would be checked by the proportionate rise in taxes. The author very justly complains of the excessive prices usually paid by railroad companies for property to be acquired for extensions and betterments; but, under the system just described, railroads would have to pay for such property no more than anybody else. Thus a prevalent cause of over-capitalizing railroad property would be removed, and not only would there result a relief in the financial burden, but a lower basis for rate-making purposes.

It is because of the very eminent fairness of this method of valuation that it is not likely to be popular. Property owners like to collect damages from some one when under compulsion to sell what is their own at a fair price for the public benefit. In fact, when a railroad is the purchaser, they too often look on the transaction as more beneficial to the railroad than to the public. At least they know that the railroad company is more likely to bid high for their property than any other individual purchaser, because land is capital, and the railroads are paying very high premiums for capital in any form. The intense sentimentality over property rights so prevalent in the United States would be sadly shattered if a man's rights to his property were reduced to just what he himself made them, and was able to pay for. As it is now, a man's property rights (within certain limits) are anything he chooses to think they are, and he does not have to sustain his exorbitant rating of them by one single item of expense beyond that of his neighbor who is similarly situated, but whose ideas are

more moderate. Property owners in this country to-day are a highly privileged class, but are placed on a most unjust and discriminatory footing with respect to each other on account of the present system of direct taxation which is without uniformity, unsupported by reason, easily responsive to corrupt influences, and, most of all, is unstable or unreliable for revenue-producing purposes. The burden falls most heavily on those who refuse to take dishonest advantage of the system's weak points. Mr. Crehore.

The important question in rate-making seems to be, not what is the intrinsic value of the property, but rather what is the capitalist's actual investment, and what portion of the earnings should be allowed to be capitalized and to become a basis for further dividends to be met out of the rates. It will be admitted that the rates must cover, in addition to all administrative and operating costs, (1) repairs and renewals necessary to keep the property up to its full efficiency, or the equivalent in the form of a fund for the protection of the stockholders, and (2) a reasonable return on the capital actually invested. To increase the rates beyond this in order to provide betterments and extensions is no different whatever from paying the stockholders larger dividends to enable them to reinvest immediately in the business, because, eventually, these betterments and extensions are capitalized and handed to the stockholders as a present. Of course, money for betterments and extension does come from previous dividends, either of these or of other stockholders, in this or in other business; but the question is, what dividend rate ought to be considered sufficient to enable the stockholders to reinvest the needful amount in betterments and extensions and have something left for themselves. With a private corporation the answer is, make as much money as you can; but with a public utility the object is to serve the public just as cheaply as possible, and, therefore, the problem begins with a determination of the minimum return which can be offered to attract capital.

It has been said by railroad financiers testifying under oath that without the practice of capitalizing earnings and offering stock bonuses with bond issues, capital could not be attracted in sufficient quantities to take care of the necessary improvements in railroad operation. These statements are doubtless true, and indicate the extreme competition for capital at present prevailing in the United States. It would seem that capital ought to know its own interests well enough not to demand such large rewards that the business itself must eventually be throttled in order to satisfy its cupidity. This situation results from an interference with the natural law of supply and demand. As the wealth of the country gradually becomes concentrated in the hands of fewer individuals, the amount of capital outside of their control becomes less. All capital is wealth of some sort. As these

Mr. Crehore. people absorb an increasing proportion of the total wealth, they acquire control of a correspondingly increasing proportion of the total capital, and automatically with the growth of their monopoly the available sources of capital diminish. Under such competition for capital as results from this monopolistic control, it cannot be expected that railroad rates will be kept low if all the demands heretofore mentioned have to be supplied from the earnings.

The President of the Pennsylvania Railroad Company issued a statement on May 12th, 1913, in which he said:

"In England the policy of railroad companies has been to pay out currently to stockholders nearly all of the net earnings, and provide for all improvements out of the proceeds of sales of capital stock. If the investors in the stock and bonds of the Pennsylvania Railroad had supplied directly all the money which has been invested in the transportation property of this Company, and if they received the entire annual net earnings from the operations of such property, they would today be getting only 4.83 per cent. upon their actual cash outlay."

Two conclusions may be drawn from this statement, one is, that if capital can be obtained on such a basis in England, it can be so obtained in this country from England by removing from our properties that most objectionable feature, over-capitalization or inflation; the other is, that if the capital for the betterments above referred to did not come from the Pennsylvania Railroad stockholders it must necessarily have been collected out of the public, or (if through bond issues) is now being collected out of the public. In other words, the difference between our method of financing railroad extensions and England's method is, that over there the capitalist puts up all the capital and receives a fair return for it, and here the public puts up most of the capital and makes a present of it to the capitalist, not only getting nothing in return for it except the improved service, but also paying rates large enough to cover dividends on the gift as well as on the capitalist's actual investment. If prevailing methods are persisted in, the logic of the situation will force an answer to this question, in financing a railroad, if the rate-payers are to furnish the lion's share of the capital anyway, what is the use of having any stockholders at all? They are merely an incumbrance.

About such a state of affairs comment is superfluous; a complete change in the system is called for. The reform has been well inaugurated by the authoritative movement to obtain a careful and complete physical valuation of railroad properties, and this movement should have the earnest and candid support of all who are interested to see better times for the railroads as well as for the communities they serve. With the knowledge thus gained, the next step will be to eliminate the load of over-capitalization now carried and to begin retiring bond issues out of the earnings, instead of refunding them and allow-

ing their share of the earnings to pass to the stockholders. The class which has so long been getting something for nothing must be taught by the removal of such opportunities to be satisfied with a fair return on its investment. Mr. Crehore.

ALEXANDER C. HUMPHREYS, M. AM. SOC. C. E. (by letter).—The writer is in complete agreement with Mr. Wilgus' statement that the task of valuing the railroads of the United States is Herculean. He has seen nothing to lead him to think that our politicians have any adequate conception of the magnitude and the almost, if not quite, insurmountable obstacles in the way of a competent solution of all the questions involved. Mr. Humphreys.

There have been some expressions from the Commission charged with the chief responsibility, to indicate that even its members do not fully appreciate the grave responsibility which rests on them.

In addition to the inherent difficulties, one has to face what the writer believes is a too common fault in the United States to-day, fear —on the part of those directly interested—of criticism and denunciation from an uninformed and prejudiced public.

Already men have been appointed to positions of influence in connection with this work who have demonstrated that they are incompetent, and, what is worse, are willing and able to labor for the destruction of legitimate property rights.

This and much more that might be said indicates that we have not to-day in the United States a proper background for these appraisals. There is need of an effective scheme of public education, not by indirection, but frank, fearless, and in the open.

Our Courts, public officials, and professors and students of economics should be included in the classes of those to be educated. The conflicting and often faulty opinions delivered by our Commissions and our State and Federal Courts demonstrate that we of the laity must not submit too subserviently to the opinions and decisions which are quoted for our control. We may have to submit temporarily in cases at issue, but we should never surrender our beliefs where we know that we, as engineers, are more completely and accurately informed than the theorists who attempt to control us. We must patiently, persistently, courageously, and openly combat the theories which we believe to be founded in error or on an incomplete survey of all the questions involved.

In order to meet those who are thus engaged in controlling the situation, however, we must be more at one among ourselves. The fact is that on some of the questions at issue engineers are not in complete agreement.

Thus the Commissions and Courts are given the opportunity to choose between opinions at variance, and so are encouraged to pick

Mr. Humphreys. and choose, item by item, until there is consolidated all possible features which are unfavorable to a fair solution of this valuation problem.

Another obstacle to a fair and consistent system of valuation is pointed out by Mr. Wilgus: the widely varying laws of the several States, not to speak of the widely varying interpretation of these, often ambiguous, laws.

Unquestionably, Mr. Wilgus is correct when he states that, as a general proposition, valuations cannot be determined accurately and fairly through reference to the records and books of account extending back through the years. It is not difficult to explain, to those qualified to understand, why this is the fact—but the fact has to be met, apart from the question of an adequate reason therefor.

Nothing could be further from the truth that, because a railroad or any property of magnitude can be inventoried, even if accurately and completely inventoried, the valuation can be determined by the inclusion of the items thus inventoried. Omissions and contingencies are not thus covered. Surely no engineer who has had any broad experience in construction could honestly so claim.

It is often the contingencies, lost to sight in the completed work, which add materially to the cost, and this outside of such overhead charges as preliminary or initiation expense, interest during construction, administrative expense, cost of procuring capital, etc., etc. For instance, if an appraisal should be made ten years from now of the New York Central Terminal, would an inventory of the existing structures disclose the legitimate and necessary cost of this great undertaking? This point is well developed in this paper.

One of the most difficult features involved in public service appraisals is that of depreciation. This subject is misunderstood by many who claim the right to speak authoritatively thereon.

If the accounts are accurately kept, so that proper discrimination is maintained between charges to construction and to maintenance, no deduction should be made for depreciation from cost to reproduce new.

Troubles in this matter have, no doubt, in part been occasioned by the more conservative practice of late in keeping accounts so as to spread the cost of final renewals ("depreciation") more uniformly over the period benefited. This leads those on the outside—and sometimes those on the inside—to think that we should deduct the assumed or estimated accrued depreciation from cost of plant. A depreciation reserve is required only to point out to us year by year that there may be certain charges against income not shown by the current expenditures and so warning us not to over-estimate our profits; but, if final renewals have not been cared for completely in the current

expenditures, then there is the liability therefor, resting against the proprietors, which must be met when parts of the plant come to be renewed. All repairs and all renewals, whether current or deferred, are chargeable against income, and so must be met by the rates. In the case of a public utility, adequately maintained and rendering efficient service to the public, to deduct for accrued depreciation according to the practice of some of our theorists, necessarily results in confiscation of investment. Mr. Humphreys.

Certain appraisers of reputation have taken the ground that if, for instance, railroad ties have an effective life of 10 years, and one-tenth of the total number is renewed each year, there is no need for a depreciation reserve, but the value of these ties as a whole should be depreciated 50 per cent. Nothing, according to the writer's way of thinking, could be more fallacious. The property, as far as this item is concerned, is thus maintained at maximum efficiency. What more could be done? Why then should one-half of this portion of the investment be confiscated? If so ordered, then we should be permitted to include a like amount as one of the overhead charges. If such an elimination is a necessary feature of railroad operation, then this is a legitimate item of cost.

Those who have not studied this subject carefully seem to think that because we should expect to allow, if we were selling, and should expect to claim, if we were buying, an allowance to be deducted from the purchase price to cover estimated accrued depreciation, therefore depreciation should be deducted in an appraisal for rate-making. On the contrary, the reason for such an allowance for depreciation in case of purchase and sale, furnishes the reason for not deducting it from an appraisal of cost new; for this indicates that there is the assumption on the part of the purchaser of a liability resting on the present owner. This is well set out in Mr. Wilgus' concluding paragraph.

This feature of depreciation the writer has treated at length in a recent paper.*

In conclusion, the writer desires to state that we, the Engineers of the United States, must appreciate that on us rests the grave responsibility of protecting the innocent investor, the widow and orphan, from spoliation at the hands of honest and dishonest interpreters of the laws of our country—Federal and State.

J. H. GANDOLFO, ASSOC. M. AM. SOC. C. E. (by letter).—The problem of obtaining the physical valuation of the railroads of the United States is probably one of the most important relating to public service corporations and properties that has ever been undertaken; and the question of rate-making, whether founded on the results obtained Mr. Gandolfo.

* "Depreciation: Estimated and Actual," read before the Institution of Gas Engineers of Great Britain.

Mr. Gandolfo. from physical valuation or not, is dependent on so many questions, both economic and financial, as to make it very difficult to discuss the matter within the limits of a single article.

To investigate this matter of valuation and rate-making properly, it is necessary to study the historical development of the railroads from their beginning, and then to analyze the entire question according to the principles of economics. This necessitates looking at the problem in a way very different from the generally accepted financial viewpoint.

Mr. Wilgus attempts to show that, from every point of view, the only just and equitable valuation to be placed on railroads for rate-making purposes, is that of replacement value new; but are his premises correct in this argument, and is replacement value new the logical figure to be used for this purpose? Would such a basis of calculation be just and equitable to the railroads, as well as to those who must pay the rates?

When a physical valuation is undertaken, no matter for what purpose, there is no doubt that the replacement value new should be estimated, taking the average cost of materials and labor for the five previous years, as is usually done; but the actual cost to date should also be determined, by reference to records which may be available, or, if not, by reconstructing all conditions as they existed at the time of the building of the road. The depreciation of the various elements entering into such a property should also be estimated at the same time. These three items can thus be determined simultaneously at very little more cost than that necessary to obtain any one of them alone, and at infinitely less cost than would be necessary to obtain each one separately. In fact, it may be said that for all practical purposes it is necessary to obtain all three of these items as a basis for study and comparison.

Referring to the sale value of the various elements entering into the construction of a railroad, such valuation is productive of no results except, perhaps, as a very poor, makeshift basis for taxation. If quantities of materials such as go to make up a railroad, were suddenly thrown on the market, it would in most cases at once depress the second-hand price of each, and thus create a price far below even the ordinary sale value. On the other hand, even taking the market sale value for estimating purposes would, as Mr. Wilgus points out, by no means give any idea whatever as to the actual values or actual costs of railroad property. As for the sale value of a railroad as a whole, such a quantity may be said not to exist, as there are no buyers for such properties in the open market. When such a property has been offered for sale, it has been bought in by a syndicate composed more or less of interested parties, and at its own price.

Mr. Gandolfo.

On page 1111,* the author states that it would be a very difficult matter to get any idea of the original cost of the railroads on account of the non-existence of records on the subject, and gives this lack of records as an argument as to why original cost to date should not be obtained and used. The mere difficulty of arriving at a result is surely no excuse for not doing the work. It is only a matter of more time and patience, to go back and, with figures based on known prices for labor and materials of the period, reconstruct a road built fifty or more years ago, than it is to reconstruct the road under present-day conditions.

Also, at various places, the author mentions different items of expense in the planning and construction of a railroad, which he seems to fear might be omitted in a physical valuation. On page 1112* he says: "Reconnaissances, preliminary surveys, and estimates of cost, revenue, and profits are needed * * *", and, on page 1117,* various construction items are referred to as matters which should not be overlooked. It is difficult to conceive that any one engaged in a valuation or appraisal of a railroad, except the merest tyro at the business, would fail to take cognizance of such items. The cost of all preliminary work, of whatever nature (including promoting), and the cost of all construction work, should be estimated, no matter for what purpose the valuation is being made. One might as well try to estimate the cost of concrete in place, and say the cost of the form work should not be taken into account.

When it comes to including in the physical valuation the cost of what Mr. Wilgus calls "the educational and development stage", however, the writer fails to see why such expenses should be estimated for this purpose. This matter is purely one of operation, and the obligations which it was necessary to issue in order to obtain working capital in the early stages of a railroad, should have been paid off from profits, and a fund kept for this purpose from accrued profits. On page 1113* the author says, "under the most favorable auspices, it usually lasts for several years". If a railroad is properly run and properly managed, the educational and development stage never ceases. For instance, the training and education of employees for their various duties never end. The study of places where economies can be practiced is something which should be in the mind of every one connected with a railroad at all times. The attempt of the Advertising Department to induce more and more travel, both freight and passenger, to patronize a given road, is also a never-ending work. As far as "errors of design and construction, as developed by operation," are concerned, these should be paid for out of profits, if there is money

* *Proceedings*, Am. Soc. C. E., May, 1913.

Mr. Gandolfo.

to pay for the work, because there is practically no limit to which such changes can be carried. To-day, expensive tunnels, long cut-offs, great trestles, deep fills, and heavy bridges, are being constructed on various railroads, simply to correct just such errors of design and construction; and if such corrections and betterments are to be capitalized as new development, what security is left for the obligations already issued against the original and now abandoned work? Of course, it must also be taken into consideration that improvements are often made for the purpose of handling increasing traffic and steadily increasing weights and loads of rolling stock. In all such cases, the only thing to do is to take the difference in cost between the old work and the new (if the cost of this new work is greater), and charge it to physical valuation. To illustrate this by a concrete case, assume a bridge, the original cost of which, complete, was \$100 000. Now, assume that this bridge is replaced by one costing \$200 000, either to correct some error in original design, or to provide for more or heavier traffic. Such a structure must be included in the valuation at its cost of \$200 000, or \$100 000 added to the original valuation of the road; but by no means should the total amount of both structures, or \$300 000, be included in any valuation, or obligations issued against this latter amount, as has so often been done in the past. Thus, it can easily be seen that the engineer who attempted to include any such feature as this, of the educational and development stage, in a physical valuation, either for original cost to date, or replacement value new, would be confronted by a peculiar problem. He would not know where to begin, or where to leave off. It would be simply a matter of personal opinion as to what and how much to include to cover some arbitrary period.

Furthermore, in this connection, it is to be remembered that, like everything else, railroading has been a slow growth, and that it has not been necessary to organize forces from absolutely ignorant material to handle the complicated equipment and traffic of to-day. The transition from the small systems beginning in England in 1825, with a few miles of track, equipped with tiny cars and 8-ton locomotives, to the great transcontinental lines of to-day, with thousands of miles of track, cars with a capacity of 110 000 lb., and great Mallet compound locomotives, was not made in a single stride. It was a slow development, and the operating force was gradually trained and organized to meet the conditions as they arose. And, further, if it could be imagined that a great railroad system was to be created new, to-day, with miles of track, modern equipment, and great terminals, even then, it would not be necessary to organize a new force from raw material. All the men holding positions of any moment

would be obtained from other railroads. A few years ago, the writer was connected with a new railroad while the operating force was being organized, and all the men in positions of any importance, including such as general superintendent, shop superintendent, heads of all operating divisions, etc., and, also, in many cases, the subordinates, were obtained from other roads. Mr. Gandolfo.

In regard to cost of reproduction less depreciation, it does not seem as if any allowance should be made for depreciation, either in an original cost-to-date valuation, or cost of reproduction new, assuming, of course, that the road has been kept in first-class condition; that an amortization fund has been provided for, to meet all maturing obligations; and that some provision has also been made for obsolescence. If such items have not been fully provided for, then the question of depreciation may become a very important one, and must be given very careful consideration, with special attention to the object for which the valuation is being made. This can be made clear by referring to the coal pocket mentioned by the author on page 1114.* If a physical valuation had been made of this property the year before it was to be renewed, and if this item had been included at its full value of $600 000, there must have been one of two provisions made, as follows: Either an amortization fund must have been created, by which all stock, bonds, or other obligations, representing the full value of the coal pocket, will be retired at the end of the next year, so that new obligations can be issued to pay for the new work; or, if the obligations against the full value of the coal pocket are not to be paid off, there must be some fund, which, at the end of the next year, will amount to $600 000 in cash, so that the new coal pocket can be paid for without issuing any further obligations. Otherwise, if no such provisions have been made, the coal pocket must be included in the valuation simply at its present value.

This case illustrates another method which may be used to estimate depreciation, and that is, when the physical valuation is being made, to estimate the amount, in a lump sum, which it would take to put each item in first-class condition for the uses for which it was intended, and then to deduct this amount from the actual cost or replacement cost, whichever plan is being followed. This method of estimating depreciation has its advantages in that it eliminates assumptions and estimates, as to the probable life of a structure; but, on the other hand, it has its disadvantages, inasmuch as it only applies strictly to present-day values, and takes no account of the fact that depreciation is apt to be more rapid in the later years of the life of any structure. This is one of the reasons why the writer

*Proceedings, Am. Soc. C. E., May, 1913.

Mr. Gandolfo. stated in his opening paragraphs, that values for depreciation should be determined for purposes of comparison and study.

On page 1115,* in discussing land values in regard to "original cost" valuation, Mr. Wilgus says, "it ignores the increment that is enjoyed by all other property owners through increase in the population and prosperity of the country"; but, in this connection, Mr. Wilgus seems to ignore the following fact. A railroad, or, in fact, any other public service corporation, does not occupy the same position, relatively to the public, or to the State, as a private citizen. A corporation has no being and no existence until created by the granting of its charter by the State, which charter defines in just what direction the corporation is to exercise its functions. A railroad corporation is thus granted rights, privileges, and immunities by the State, which are not accorded to the individual. It is a fundamental axiom of both law and economics that something cannot be obtained for nothing, and thus, in return for these grants, the railroad must give up some things to the State, which the latter cannot demand from the individual. In regard to this question of land, it must be remembered that, especially in the early days of railroading in the United States, large grants of land were made to these corporations by the State, either without any compensation whatever, or at a merely nominal figure. It is not equitable that the present generation, having lost this land through no fault of their own, should now in addition be indirectly taxed for what their ancestors gave away without compensation.

In the following paragraphs the writer wishes to point out some additional anomalies and contradictions which would occur if the replacement value new was used as a basis for rate-making purposes.

According to an old print, the great Tring cutting, made in 1837, on the London and North Western Railway, was excavated by hand, and the spoil was removed in hand-barrows, guided by men, and pulled up inclines on the sides of the cutting by ropes passing over pulleys and worked by horse-power. In estimating such a piece of work for replacement value new, should these conditions be duplicated, only with present-day prices for labor and material, or should modern steam-shovel conditions prevail? It seems to the writer that, in a case like this, the railroad might find that, in spite of high labor and material prices, the cost of such a work would be much less than the original figure, and thus be an injustice to the company.

Referring to the temporary trestle work mentioned by Mr. Wilgus on page 1117,* on many of the early roads in the United States such structures were built of timber obtained along the line. It surely

* *Proceedings*, Am. Soc. C. E., May, 1913.

would not be just to estimate a value for such a structure based on present-day figures for the labor and materials entering into it. Mr. Gandolfo.

About seven years ago, the cost of a certain class of steelwork, erected in place, was 4.07 cents per lb. Since that time this price has not been reached, but the same class of work has been done as low as 2.87 cents per lb., or a difference of 29½ per cent. It would not be just to say to the railroad which had paid the higher price, "Here, you must reduce your capital, because the work can now be done cheaper". This money was honestly invested, and it would be unjust to wipe out a part of such invested capital.

Another objection against replacement value new for rate-making purposes, is that it would be a constantly varying quantity, whereas original cost to date would only have to be corrected for such additions and betterments as were added from time to time.

In conclusion, it seems to the writer that for rate-making purposes, the total cost of the work to date, is the figure to be obtained. This figure represents the actual amount of capital invested in the enterprise. It may be argued that some railroads have depreciated, instead of appreciated, in value, and that no rate could be fixed, which would give a fair return on the investment. This is true, but in such a case the enterprise is not a success, the company is insolvent, and should be treated as such.

It may also be argued, as Mr. Wilgus indicates, that this method of valuation puts the older roads in a much more favorable position than those built at a later date. This is also true, but it was a question for the promotors and builders of these later roads to consider in their preliminary estimates, not for the State and the people to consider now.

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PAPERS AND DISCUSSIONS

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MODERN PIER CONSTRUCTION IN NEW YORK HARBOR.

Discussion.*

By Messrs. F. R. Harris, J. P. Snow, Tyrrell B. Shertzer, C. H. Stengel, L. D. Cornish, L. J. Le Conte, and Chandler Davis.

F. R. Harris, M. Am. Soc. C. E.—The information in this paper is of the greatest value, especially as so little on this subject is to be found in technical literature. Mr. Staniford deserves hearty thanks for his effort to enlighten the Profession as to the current practice of the Department of Docks and Ferries of New York City. Mr. Harris.

The speaker has had some experience in the design and construction of wharves and piers at various ports on the Atlantic Coast, especially in New York Harbor, and feels that it is his duty to invite attention to certain parts of this paper, as his investigations have shown that the conclusions arrived at and implied by Mr. Staniford are not entirely beyond question and challenge.

About four years ago, the speaker made a thorough investigation of certain projected pier or wharf construction at the New York Navy Yard. Several such wharves had been built there, and, under a project for the development of the Yard and the improvement of the waterfront, two more were projected, with the probability that these would be followed by the construction of five others. Another wharf, designed by the speaker, of the general type which had been used at the Navy Yard for some time, was just being completed.

Being familiar with the current practice of the Department of Docks and Ferries, he made a careful investigation of the design then used by that Department, particularly the concrete deck on timber piles and caps. It seemed especially desirable to use such a design on account of its reputed economy in first cost and its apparent advan-

* Continued from September, 1913, *Proceedings*.

Mr. Harris. tage in being fire-retarding. The results of this investigation were not entirely in harmony with the conclusions set forth in this paper.

It was found that the cost of a concrete deck wharf would exceed that of a timber deck wharf, this conclusion being reached in spite of the contract price obtaining on the City piers at South Brooklyn. The speaker interviewed the contractor for some of these piers, and learned that the price at which they were being built was not a fair criterion as the cost was considerably in excess of the sum the contractor was receiving. This served to confirm the estimates which had been made, particularly when the figures were taken up with various contractors. It became evident that, if bids were invited for piers or wharves with a concrete deck, and an alternate with a 4-in. deck and 3-in. sheathing on top of it, the cost of the concrete pier would be higher by about 25 cents per sq. ft. The cost of the substructure—the piles and caps—would be practically the same in both types, with a slight modification which will be mentioned later. The superstructure, which could be considered as the deck structure, would consist of rangers, 4-in. decking, and 3-in. sheathing, in the case of timber wharves; of 10½ in. of concrete and 2 in. of asphalt paving, in the concrete deck wharf. The lumber in the timber deck wharf would be about 8½ ft. b. m. per sq. ft., which, at $42 per thousand ($35 for lumber and $7 for labor), would amount to 35.7 cents per sq. ft. This should be compared with 0.03 cu. yd. of reinforced concrete and 1 sq. ft. of asphalt, in the concrete deck wharf, estimated at 60 cents per sq. ft., or about 25 cents per sq. ft. more than the timber deck wharf, which is an additional item in favor of the latter.

The deck structure of the concrete deck wharf would weigh practically 150 lb. per sq. ft., thereby decreasing its live-load carrying capacity to that extent; the timber involved would only weigh 34 lb. per sq. ft., showing that the timber wharves would have a carrying capacity of 116 lb. per sq. ft. in excess of what the same foundation would carry with a different type of deck. Therefore, in order to make the two systems comparable, additional piles, and probably caps, would have to be provided in the concrete deck wharf, making the difference in cost even more favorable for the timber deck wharf. The speaker fully appreciates the fact that special conditions in taking care of the transportation and shipping of valuable materials in New York City involve fire risk and insurance, and that probably on this account the Department of Docks and Ferries was well warranted in substituting the concrete deck for the timber deck; and although this reason alone justifies its use, it is misleading to justify it on the basis of cost and economy.

As an objection to timber deck wharf construction, Mr. Staniford has mentioned the necessity of repairing and relaying the deck sheath-

ing on account of its destruction by traffic. The speaker is also impelled to question the implication that this timber deck sheathing would have to be replaced more frequently than the asphalt wearing surface. From his experience with asphalt pavements, he is inclined to believe that a 3-in. deck sheathing would outlast the asphalt wearing surface, and—even if this conclusion were not entirely correct—that it would be cheaper to repair or replace the 3-in. deck sheathing than the asphalt pavement wearing surface. Mr. Harris.

Repairs is a very important item, when wharves are not of a permanent type, as is the case with those on timber piles and having either concrete or timber decks. As Mr. Staniford states, it is necessary, at intervals, to replace piles and caps, such repair being caused by decay from mean tide up, except, of course, in harbors where marine borers are found, where a timber pile wharf of any type cannot be considered in any way a permanent structure. The destruction of caps and stringers by rot requires serious consideration, especially as there is a tendency from year to year to deliver commercial timber of poorer quality, containing more sap. It is a well-known fact that inspection rules in relation to commercial lumber have become less and less rigid in recent years. A wooden deck wharf is not considered a permanent structure, and frequent repairs and replacement of the timber work and the piles are expected. These are readily made, as it is not difficult to remove the deck, replace caps, or drive additional piles. The speaker understands that a concrete deck wharf is considered by the Department of Docks and Ferries as more permanent, although why it should be he cannot comprehend, because it is apparent that the timber piles will need repair and replacement just as often as in the timber deck type; the pile caps also will need replacement just as often, and probably oftener, because the concrete slab will tend to keep the tops of these caps damp and in a condition to invite rapid decay. It will be extremely difficult to make repairs on one of these wharves. The speaker need not compare the task of removing timber planking with that of removing a 10½-in. reinforced concrete slab. The expense of cutting through such a slab, with its reinforcement, will be considerable. It is understood that wharves of this type have not been in use long enough to have required repair, but, when such repairs are necessary, there is no doubt that the difficulty will convince the Department of Docks and Ferries that a permanent deck structure on a temporary foundation is not the very best type to adopt.

There seems to be a generally accepted opinion that there are no marine borers in New York Harbor. This is an error. Marine borers are found in the Lower Harbor, and, perhaps, under certain conditions, which are likely to develop with wind and tide, they will be found on the South Brooklyn shore. A wharf of the Navy De-

Mr. Harris. partment at Fort Lafayette, constructed about 10 or 12 years ago, was examined recently by the speaker, and preparations were made to repair it. It was found that in many instances the piles were entirely gone, having been destroyed by sea borers, and that the caps and stringers were in such a condition, on account of rot, that it would be an economy to replace the entire wharf with a new one.

In the investigation of pier construction in the vicinity of New York, with the idea of adopting a type for the Navy Yard, as previously stated, both kinds of wharves used by the Department of Docks and Ferries were considered carefully. Previous to that time, there had been used in the Navy Yard a type consisting of a pile platform at low water, surmounted at the sides and ends by masonry retaining walls, the contained space being filled with earth compacted and paved over. The last pier of this type—known as Pier D—designed and constructed under the speaker's supervision, cost about $3.25 per sq. ft.; this included wood block paving on a concrete foundation, two lines of standard gauge railroad track and one line of 18-ft. gauge, 40-ton, crane track, and also fresh- and salt-water pipes, air pipes, and electric conduits. In making the study referred to, an endeavor was made to reduce this first cost and still obtain a substantially permanent structure. It is apparent, of course, that the pile foundation of such a wharf carries a very heavy dead load, namely, the masonry retaining walls and the 8 or 9 ft. of earth filling; or, in other words, that more than half the foundation piles are used in carrying a dead load, and to that extent are an absolute loss in so far as the live-load capacity of the wharf is concerned. The investigation and estimates established the fact that a timber wharf would cost about $1.00 per sq. ft., and a timber wharf with a concrete deck, $1.25 per sq. ft. The items of maintenance and repair for each type were considerable, and in the case of the concrete deck, the difficulty of such maintenance and repair, entirely eliminated it from further consideration. The speaker, consequently, evolved a design in which he used a reinforced concrete deck, lighter than that of the Department of Docks and Ferries, but, to some extent, similar, and this was carried by reinforced concrete columns resting on a timber substructure. The latter consisted of piles cut off slightly above low-tide datum, and fastened to the cross-caps with oak tree-nails. The reinforced concrete columns were cast on shore. The bases were dovetailed, let into the caps, and wedged to them with spruce wedges. They were also fastended by stringers or clamps which were attached to the caps, and the space between the abutting longitudinal clamps was filled with 3 by 12-in. chocks or filling pieces. The usual brace piles at the side were used in the timber substructure. All the subaqueous work was fastened and wedged, as far as possible, oak tree-

nails being used and metal fastenings avoided. The designs were of two types, one with girders and beams to support the concrete deck slabs, and the other using the mushroom system, each column unit being flared out so as to reinforce the criss-crossing of the main deck slab reinforcement. The preliminary estimates indicated that this mushroom type would be less expensive, but the bids received proved this to be in error, and, therefore, the girder-beam type was adopted. Two of these piers have been completed. They have a creosoted wood-block pavement over the concrete deck slab, two lines of standard gauge railroad track, one on each side of the wharf, and two lines of subway, one on each side of the wharf; with fresh- and salt-water pipes, pneumatic lines, and telephone and electric conduits for cables still to be placed. These piers were estimated to cost $1.60 per sq. ft., but this was based on the use of piles 65 ft. long. On actually proceeding with the preparation of detailed plans, and an investigation of the site, it was found that piles 85 ft. long would be required, and this, together with the expense of inshore connections for pipe work, railroad tracks, etc., increased the price of the work, so that the actual cost of these two piers has been $2.04 per sq. ft. After the experience gained in the construction of these piers, the speaker is convinced that piers of the size used in New York Harbor, and without the subway and pipe lines, track work, etc., could be constructed for less than $1.60 per sq. ft. Mr. Harris.

It is apparent that piers of this type may safely be considered permanent, as far as concrete immersed in salt water is permanent. Every precaution which experience at the Navy Yard could suggest was taken to make this concrete work permanent, but so much difficulty has been had there with concrete in salt water as to suggest that this is not a permanent material in salt water. Dry Dock No. 2, at the New York Navy Yard, was originally built of timber, and after very voluminous discussion before this Society, years ago, condemning timber structures of this sort, was rebuilt partly of concrete. It is now undergoing extensive repair. Considerable sums are being expended in replacing the facing of the concrete altars and floor, which has deteriorated and disintegrated to such an extent that it is possible to use a pick and shovel in removing the concrete.

The concrete unit columns in the wharves mentioned were cast on shore, a 1:2:4 mixture being used, containing a water-proofing compound. They were allowed to season for some time before being placed in the water.

The speaker's principal motive in discussing this paper is to call attention to the fact that the design used by the Department of Docks and Ferries is a composition of a permanent and a temporary structure. Special attention is called to the fact that it would be diffi-

Mr. Harris. cult or impossible to repair the temporary part—the foundation itself—without also destroying the permanent part, thus making the entire structure only temporary. He also desires to bring out the fact that, with slight additional expense, the permanent part of the structure could have been carried down to mean tide level, thus making the entire wharf permanent, as far as wharf structures of this character and of concrete can be permanent. In other words, in the upper part of New York Harbor, where timber piles will not be attacked by sea borers, and can be considered permanent from low tide down, the composition of timber and concrete, if made as described for the Navy Yard, furnishes a permanent structure at a low first cost. The speaker gladly acknowledges that the investigation made by him first brought to his attention the inconsistency in Mr. Staniford's design, and in an effort to retain its good features and at the same time avoid the expense of reinforced concrete piles, he succeeded in evolving the design he has described.

In reply to Mr. Snow: The speaker does not think that conditions in southern yards can be compared with those in the New York and Boston Yards. He believes that, in southern waters, concrete is free from deterioration partly because of the absence of extreme temperature changes which open up hair-like cracks in the surface, thus permitting the entry, or the attack, of salt water. It has also been stated that a gelatinous substance forms on the face of the concrete, between high and low water, and protects the surface. The speaker believes that even a very thin facing of granite will protect a structure from deterioration, although the joints, after a while, will require re-pointing.

Mr. Snow. J. P. Snow, M. Am. Soc. C. E.—There are many examples of concrete construction in sea water in Boston Harbor, and in every instance known to the speaker there has been serious disintegration between high and low tides. This trouble is attributed to the action of frost. The damage is readily repaired with a cement gun, if not allowed to become too extensive. It would be of great interest to ascertain if this sort of disintegration occurs in southern waters where there is no freezing, and the speaker would be glad to have Mr. Harris state, if he knows, whether Government works of this class suffer between high and low tides in southern harbors?

Mr. Shertzer. Tyrrell B. Shertzer, Assoc. M. Am. Soc. C. E.—In 1906, the concrete was placed for one of the abutments of a large highway bridge across the Fore River, a branch of the Harbor of Portland, Me. This abutment was constructed with a concrete base, granite facing, and concrete backing. The plans called for a sand-fill to be placed across the front and ends of the structure to a little above the elevation of the bottom of the granite, this fill to be paved so as to resist wave

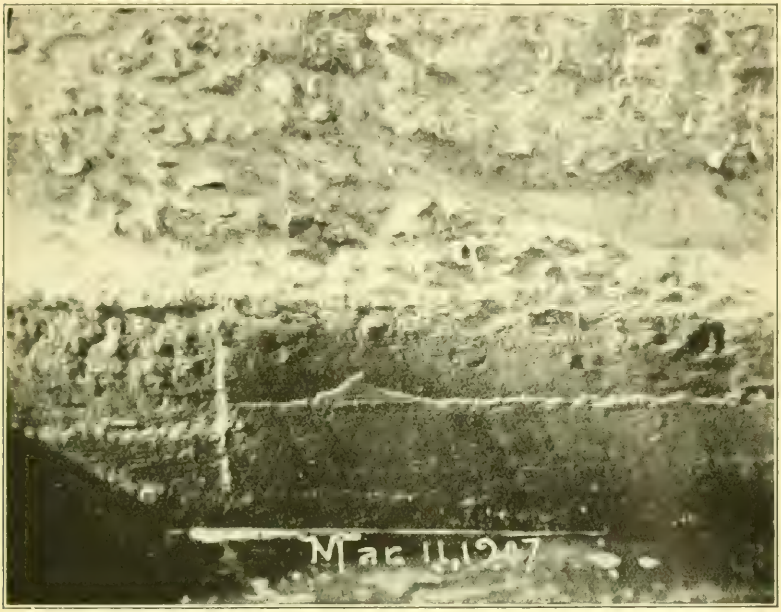

FIG. 10.—DISINTEGRATION OF CONCRETE, ABUTMENT "Q", VAUGHAN'S BRIDGE, PORTLAND, ME. ONE WINTER'S EXPOSURE. CONCRETE IN LOWER PART PROTECTED BY SAND. SLOPE OF SAND FILL SHOWN AT LOWER LEFT CORNER.

FIG. 11.—ABUTMENT "Q", VAUGHAN'S BRIDGE, PORTLAND, ME.

action. Conditions were such, however, that all the fill could not be placed before cold weather set in. Mr. Shertzer.

The winter of 1906-07 was a severe one, and it was noticed that the unprotected concrete base was disintegrating where exposed. In the spring of 1907, after the ice had gone out, the exposed surface was found to be disintegrated to a depth of more than 2 in. That portion of the concrete which had been protected by the sand, however, was found to be in perfect condition, and, at the elevation of the sand protection, there was a sharp and distinct limit to the area disintegrated. It will be seen clearly from Fig. 10 that the portion of the concrete below the sand line still shows the saw marks of the form boards, whereas that portion above the sand line is badly disintegrated. The small hole seen at the upper right-hand corner of the photograph was drilled for the purpose of ascertaining how deeply the concrete was affected. The slope of the edge of the sand-fill, which was excavated to permit of taking the photograph, may be seen at the lower left-hand corner. This photograph shows a portion of the same face of the base as appears in Fig. 11, the photograph of the entire abutment.

These conditions led to a series of experiments to ascertain, if possible, the causes of the phenomenon. In the fall of 1907, several sets of standard briquettes were made of both neat cement and of a 1:3 mix, making all the possible combinations of mixing with fresh and sea water, and using the local bank sand and standard Ottawa sand. Three 12-in. cubes were also made of samples taken from the regular machine-mixed concrete. These briquettes were made and placed at the beginning of cold weather in the winter of 1907-08. They were distributed as follows: Sets of three briquettes of each type and enough for the regular 7-day, 28-day, 3-month, 6-month, and 1-year tests were stored in the laboratory in fresh and sea water; buried in the sand at a depth of about 1 ft. above high water, at mean tide, and below low water; and placed in crates above high water, at mean tide, and below low water. One cube was placed on the flats above high water, one at mean tide, and the third was lowered to the bottom of the river.

Chemical tests were made during these experiments by the professor of chemistry at the Portland High School to ascertain the effects of the materials and water.

Unfortunately, the long-time tests could not be made on the briquettes, as the City Hall at Portland was destroyed by fire early in 1908, and the laboratory and all the records and data were lost, so that what appears here is from memory only.

Such of the tests as were made showed that the briquettes stored in both fresh and sea water in the laboratory, those buried in the

Mr. Shertzer. sand, and those exposed in the crates above and below water, gave practically identical results, and those stored in the crates at mean tide were entirely disintegrated after from 2 to 3 weeks of exposure to freezing weather.

The large cubes were made and placed in the spring of 1907, and were exposed throughout the summer of 1907 and the following winter. No effect was observed as the result of the summer exposure, and after about a year's exposure those cubes placed above and below water were still in perfect condition, the one exposed at mean tide, however, had been reduced to about 4 in. as the result of exposure during the winter.

In the spring of 1907, as soon as weather conditions permitted, the loose material was removed from the disintegrated face of the base of the abutment, the surface was plastered up, and the rest of the sand-fill and the pavement placed. In the fall of 1912 some of the rip-rap and sand protection was removed, and it was found that the trowel marks in the plaster used in smoothing up were still distinct. The sand lying within the tidal range has been saturated with sea water for more than 5 years, and it would seem that if the action were a chemical one it would have affected the concrete.

It would seem that the only conclusion which can be drawn from the above-mentioned experiments is that the disintegration was caused by purely mechanical means, and that if the concrete is protected from the direct action of alternate freezing and thawing, such as occurs within the tidal range, there will be no disintegration.

William H. Burr, M. Am. Soc. C. E., was the Consulting Engineer, and the speaker was Resident Engineer, on this work.

Mr. Stengel. C. H. Stengel, Assoc. M. Am. Soc. C. E.—In 1907, when the Virginian Railway coal terminals were constructed, it was necessary to build permanent foundations for the large steel superstructure which extended 1 000 ft. into the waters of Hampton Roads. Open pile foundations, capped with grillages, were out of the question, as the waters were infested with teredo. The design decided on was monolithic concrete piers, with heavy rectangular bases, built on piles in 30 ft. of water, the piles being cut off 1 ft. below the mud line. On the rectangular bases, battered pier sections were built to a level approximately 4 ft. above high water. All this concrete was deposited under water by tremies 12 in. in diameter, and allowed to set for several days; then the forms were removed and the sheeting was pulled.

Under the conditions existing at the time, and on account of the manner in which this work was done, if there were any chemical action to deteriorate concrete, due to the effect of sea water, it would have been noticed, as a careful inspection of all the piers was made by divers; also, if there was any destruction between high and low

water, due to changes in temperature and freezing, it would now be perceptible; as it is, these piers are in as good condition as when built. Mr. Stengel.

The speaker, however, does not doubt that in piers built under similar conditions in northern harbors, where the temperature changes are considerable, and alternate freezing and thawing takes place between high and low water, some mechanical destructive effect might be experienced, as concrete built under the conditions stated never becomes dry, and the contained moisture, in freezing near the surface, would expand and gradually disintegrate the concrete.

This effect, however, should not obtain with concrete blocks, built and matured on land and then set in place between high and low water; and there are a number of examples around New York Harbor to substantiate this statement.

The mixture of concrete used in the construction of the foundation for the coal piers was $1:2\frac{1}{2}:5$, with gravel.

L. D. CORNISH, M. AM. SOC. C. E.—The question of the deterioration of concrete in sea water, naturally, was one of the first subjects of investigation by the designing force of the Isthmian Canal Commission in connection with the locks for the Panama Canal. Mr. Cornish.

Data on this subject were collected for about two years and, after careful consideration, the conclusion was finally reached that recorded experience failed to show that deterioration of concrete might be expected in tropical sea water, provided ordinary care was exercised in the selection of the ingredients, and in the mixing and placing.

Experience on the Isthmus, thus far, has shown no reason for a different conclusion, and the speaker is of the opinion that the causes for authenticated cases of deterioration must be sought in mechanical action or poor materials, rather than in chemical action of ordinary sea water on first-class American Portland cement concrete.

L. J. LE CONTE, M. AM. SOC. C. E. (by letter).—Extensive harbor improvements call for strict economy in first cost and annual maintenance, and length of life. Recent developments on San Francisco Bay have given rise to some new features which may be interesting. The final conclusion is that a solid-mole development is much superior in every respect to the ordinary pier, when a wide view is taken of the whole situation from both financial and commercial standpoints. Mr. Le Conte.

As the waters of San Francisco Bay are largely infested with the marine pests, teredo and limnoria, all important structures are made of creosoted piles or concrete piles and superstructure.

First Case.—An Ordinary Pier.—For ample commercial purposes, the pier should be at least 200 ft. wide and 1 000 ft. long, with a slip alongside, 300 ft. wide, for handling the shipping, and, without any warehouses, tracks, derricks, movable cranes, etc., would cost probably \$315 000.

Mr. Le Conte.

Second Case.—A Solid Mole.—The mole would be surrounded on three sides with a 50-ft. commercial wharf. The same amount of money will build a solid mole, 500 ft. wide and 1 000 ft. long, and a slip alongside, 400 ft. wide, for handling vessels. This simple structure, like the pier mentioned, is supposed to be without warehouses, tracks, derricks, movable cranes, etc.

A little consideration will show the advantages of the mole development. The dock frontage of the pier development is 2 500 lin. ft.; that of the mole development is 2 900 lin. ft.—a difference of 16% in favor of the latter. In the case of the mole the area of dock flooring to be kept in efficient repair is only about 60% of that of the pier development, which is quite an important item of annual expense. Besides these advantages, the mole has nearly twice as much warehouse room, and a 200-ft. roadway in the center for railway and general commercial traffic, the paramount convenience of which cannot be overestimated.

Mr. Davis.

CHANDLER DAVIS, M. AM. SOC. C. E. (by letter).—New York Harbor, without doubt, is the most important one in the world. It possesses many advantages over other seaports, not the least of which is the small range of tide. As tidal and wet basins are unknown, these expensive constructions are eliminated from the problem. The current in the river is not so strong that the largest ships cannot be warped into their slips without much difficulty, although at times it may require several hours—it took 5 hours to dock the steamship *France*. Such cases, however, do not occur so frequently that the pier and slip system should be condemned, for it is, without doubt, the best and most economical layout which could have been adopted. It permits the handling of more ships in a given length of river-front than any other plan.

If the scheme adopted at Antwerp had been introduced at New York, a steamship of the dimensions of the *Imperator,* would require about 1 000 lin. ft. of bulkhead for docking purposes; with the plan used in New York Harbor this length of river-front is sufficient to permit the working of four such ships simultaneously. The late General McClellan, the first Chief Engineer of the Dock Department, was wise in developing and perfecting the system he found in use.

The Hudson River has been encroached on to such an extent that the War Department has finally decided that the pier-head line must not be moved farther out into the river, and all encroachment must be stopped. This attitude of the Government is well taken. When one considers the size of the modern ship, he will realize that, if such extension were permitted, there would soon be insufficient width of clear water to allow the safe handling of these vessels, for at least two ship lengths are required to turn them. At the present time there

is barely the necessary width left between the pier-heads, and there is great difficulty in handling the ocean liners. If relief is required, it must be sought by moving the bulkheads inland or locating the docks at points other than on the Manhattan shore of the Hudson River. Mr. Davis.

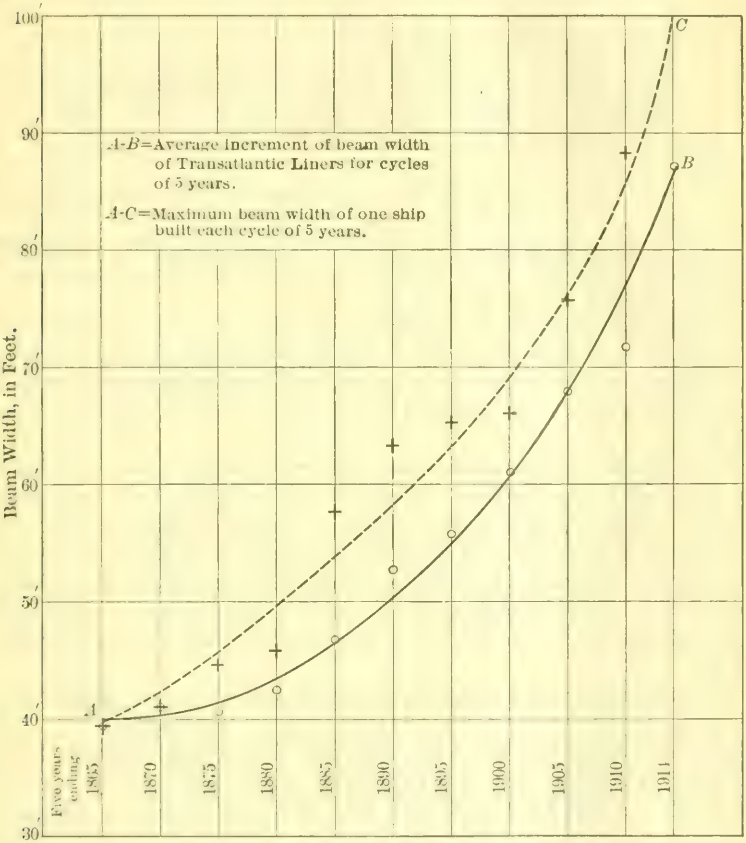

FIG. 12.

The naval architect is increasing not only the length of ocean liners, but also their beam. This is a very important factor, and must be considered in laying out new work. Fig. 12 shows the average increase in beam of ships, for every five years from 1865 to date; it will be seen that it has been more than doubled. The *Labrador*, launched in 1865, had a beam of 39.2 ft.; the new Hamburg-American liner, *Vaterland*, will have a beam of about 100 ft., or two and one-half times that of the *Labrador*.

Mr. Davis. The open water between two adjoining piers, called the "slip", should be of sufficient width to allow the working of two steamers in the same slip at the same time. The following formula will determine the required width, provided railroad car-floats are not used, as is the case with fruit ships:

$$W = 2F + 4C + 2B + 2L + 50.$$

W = the required width of slip;
F = the width to be allowed for the fender system of the piers, including the rolling log, if one is used;
C = the extreme width of the coal barges;
B = the beam of the ship;
L = the extreme width of the cargo lighters; all expressed in feet.

In the center of the slip, a width of 50 ft. of open water is required to facilitate the handling of the lighters and scows without interfering with the working of the ship.

The general tendency is to sacrifice the slip in order to build large, imposing piers. A width of 90 or 100 ft. for a pier is ample to care for the cargo of the largest ships afloat, and it is quite unnecessary to exceed this, unless it is intended to use such piers as store- or warehouses.

Ships of the *Imperator* or *Vaterland* type, having a beam of about 100 ft., would require slips about 400 ft. wide, if two such ships are to be docked in the slip at the same time. These points should be carefully considered in laying out a plan for docks, as congested slips increase the cost of handling cargoes and coaling. The dimensions of the largest vessels trading with the port must be considered in the design, and a study must be made of their gradual increase in size.

The materials which enter into pier construction are many. For a long time only wood was used, but recently the wooden decks and rangers have been replaced with concrete. The North German Lloyd Steamship Company was the pioneer in such work in this part of the world. After the disastrous fire which destroyed its Hoboken docks, the plant was rebuilt with concrete decks and fireproof superstructures. This scheme has been still further developed by the City of New York, and to-day the construction above the caps or clamps is of reinforced concrete. This construction, however, leaves the piers vulnerable between low tide and the deck. The Hudson River is free from the *Teredo navalis* and other wood-destroying borers, and will probably remain so until some other method is found of disposing of the tons of filth which are daily dumped into the river. The piles below low water, therefore, are, for all practical purposes, indestructible. The few points where protection against worms has been found

necessary need not be considered here. In all sections of the port, however, the piles above mean low water will deteriorate and eventually will have to be replaced. The present design of decking used by the City will make such work expensive and extremely difficult. The design, therefore, should include the entire pier from low water up, if it should be desirable to continue the use of wooden piles. A general plan for this could probably be worked out, and would only need to be modified to suit local conditions. Mr. Davis.

The Dock Department is working along the right lines, and is attacking the problems, as they present themselves, in a conservative, but thorough manner.

MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

ADOLPHUS BONZANO, M. Am. Soc. C. E.*

DIED MAY 5TH, 1913.

Adolphus Bonzano was born at Ehingen, Wurtemburg, Germany, on December 5th, 1830. He was the youngest of four brothers who came to the United States, three of whom had distinguished careers. He, however, was the only one to follow the Engineering Profession.

Mr. Bonzano was educated at the gymnasia of Ehingen, Binsdorf, and Stuttgart. After the usual thorough training in these German schools, he came to Philadelphia, Pa., for further study, and particularly to perfect himself in the English language and in the customs of his adopted country. His father and other members of his family had emigrated to Texas in the Thirties, where they formed a number of German colonies in the interior, Gillespie and the adjoining counties, then an unsettled wilderness, but now part of the most prosperous portion of the State.

In 1852, Mr. Bonzano, who had early shown marked mechanical and engineering talents, recognized the great possibilities which the iron industry offered in the development of the country, and determined to supplement his academic studies by actual shop experience. He entered the Reynolds Machine Works, at Springfield, Mass., as an apprentice, and, at the end of his apprenticeship, became its Superintendent. For several years after this he was employed by several industrial and railway companies in various capacities in shop work, becoming one of the skilled mechanical superintendents of those days. During this period he became interested in bridge work and gave it such study as the early days of bridge history in the United States permitted, becoming a pioneer in its development. Finally, in 1865, he engaged with the Detroit Bridge and Iron Works as Superintendent of Bridge Construction, and, from that day until his retirement from business in 1898, he was an influential factor in the bridge industry, and in its formative period, particularly, his unusual talents were shown in his boldness of design, his advances in specifications, and his ingenuity in erection problems.

* Memoir prepared by F. A. Molitor, M. Am. Soc. C. E.

After serving three years with the Detroit Bridge and Iron Works, where his specialized work attracted much attention and earned him a broad acquaintance, he removed to Phœnixville, Pa., and with David Reeves, M. Am. Soc. C. E., and the late Thomas Curtis Clarke, Past-President, Am. Soc. C. E., assisted in the organization of the firm of Clarke, Reeves and Company (Phœnixville Bridge Company), becoming a partner and its Chief Engineer. In the early days of the partnership, Mr. Bonzano made the plans, strain sheets, estimates, bids, and shop drawings. The firm rapidly became a leader and acquired the highest rank among bridge companies, many of the largest and most famous structures in the United States having been designed, built, and erected by it. In 1884, the firm was dissolved, being succeeded by the Phœnix Bridge Company, with Mr. Bonzano as Chief Engineer and Vice-President. For the next ten years he devoted all his time, experience, and business acumen to this company, his reputation probably reaching its zenith during this period.

The strain resulting from his professional activities of more than forty years, and the ever-increasing responsibilities of modern bridge business, determined him to reduce his activities, so he resigned from the Phœnix Bridge Company in 1893 and opened an office as Consulting Engineer in New York City, with his old friend and associate, the late Mr. Clarke, as partner. This association continued until 1898, when Mr. Bonzano retired from all active professional and business work, making his home in Philadelphia, Pa., where, surrounded by his family and many friends, he passed the evening of his life in quiet enjoyment.

In the work of the pioneer and formative period of American bridge construction, Mr. Bonzano had no peer. His unusual talents and attractive personality enabled him to place what was then bold and original bridge design under contract, and to this day many of his bridges are in use, carrying loads far in excess of their original design. He was also able to put the bridge business on a sound and proper basis, from specifications to erection, and in so doing he earned the appreciation of his associates and the grateful remembrance of their successors.

Mr. Bonzano's professional activities resulted in the building of many important bridges by his companies throughout America and in foreign countries, but only a few of these monuments to his genius will be mentioned here:

The Pecos Viaduct, 2 100 ft. long, carrying the Southern Pacific Railroad over the Pecos River at a height of 320 ft., built in 1890. The Red Rock Cantilever Bridge, over the Colorado River Canyon, on the Atlantic and Pacific Railway (now the Atchison, Topeka and

Santa Fé Railway). The Kinzua Viaduct, 300 ft. high, on the Erie Railroad. At the time of its construction this viaduct was the highest structure in the world, and for boldness of design and erection methods astonished railroad and engineering circles, and was thoroughly discussed in the technical and daily press. The Chesapeake and Ohio Railroad Bridge carrying a double-track railroad, two roadways, and two sidewalks, over the Ohio River at Cincinnati, built in 1888. This bridge, having one 550-ft. and two 240-ft. spans, was at that time the longest double-track span ever constructed. The Susquehanna River Bridge at Sunbury, Pa., built in 1882 for the Philadelphia and Reading Railroad, and the Columbia Bridge, Fairmount Park, Philadelphia, with seven spans aggregating 1 000 ft., built in 1886, also for the Philadelphia and Reading's double-track line. The Girard Avenue Bridge, at Philadelphia, 1 000 ft. long and 100 ft. wide, built in 1874, was one of the best examples of American municipal bridges.

Mr. Bonzano also had a large, if not the principal, share in the development of the modern draw-span, having designed and built some of the most notable structures of this type. The 274-ft. double-track draw of the New York Central and Hudson River Railroad, at Albany, built in 1870, was one of the first large railroad draw-spans. The construction of its turn-table embodied many original features designed by him, which later became standard practice. Some of the other and earlier draws built by Mr. Bonzano were the Harlem River Bridge, with a 300-ft. double-track draw-span, built in 1880; and the Albany and Greenbush, with a 400-ft. draw, carrying a double-track railway and roadway, built in 1881. As early as 1878 he built the 410-ft. through single-track draw-span of the Susquehanna Bridge, on the Philadelphia, Wilmington, and Baltimore Railway, then the longest draw in the world. All these bridges, except the Albany and Susquehanna draw-spans are still standing and carrying modern loadings.

Mr. Bonzano's inventive and mechanical genius was shown in the minor draw mechanisms. He was the first to use the locking roller with a pair of links at the draw end, and soon after modified this by the knuckle-joint. The use of a vertical screw for operating the locking mechanism was original with him.

He was also the pioneer engineer in the development of the first elevated urban railroads. The Sixth and Ninth Avenue Elevated Railroads in New York City with their Phœnix columns, now nearly 40 years old, are monuments to his boldness of professional thought as well as business judgment. He also built all the Kings County (Brooklyn Rapid Transit Company) Elevated Railroad lines.

The merits of the well-known Phœnix column, which was invented by the late Samuel J. Reeves, M. Am. Soc. C. E., of the Phœnix Iron

Company, and was then only used in building construction, was at once recognized by Mr. Bonzano, and he was the first to introduce it in bridge compression members and to exploit its advantages. He made the designs of the details necessary to apply the Phœnix column to bridge construction, and it remained as the best bridge compression member for many years. This is shown by the fact that there never was a failure of a Phœnix column in a bridge, no matter how much the latter was overloaded.

Mr. Bonzano gave many inventions to the modern world, as the records of the Patent Office testify. Chief of these is the popular rail joint, bearing his name, which he called his "little bridge", an epigrammatic expression which, with the ingenious thought that prompted the invention, was typical of him.

Although Mr. Bonzano will be remembered by the Profession as one of the pioneer and able bridge engineers of his age, his contemporaries will particularly remember him for his fine and unusual personality, and his lasting friendship for them. As an employer he was kindly and considerate, and many engineers of this generation will remember him for his helping and guiding hand when they were his apprentices and students. He numbered among his friends every one who knew him, his kindly disposition and genial manner making him a friend of everybody. It has been truly said that he never had an enemy. His charity, however, unostentatious and liberal as it was, will never be known; all we know is that he never refused a helping hand.

Mr. Bonzano was a Member of the Canadian Society of Civil Engineers, the American Society of Mechanical Engineers, the American Society of Mining Engineers, the Franklin Institute, the Union League Club of Philadelphia, and the Engineers Club of New York.

In 1857 he was married to Laura J. Goodell, in Detroit, Mich., and they had two sons, Hubert A. and Maximilian F. He is survived only by the latter, who is a Member of the American Society of Civil Engineers.

Mr. Bonzano was a talented musician, having been a skillful pianist and an able organist, and to the end he kept up a lively interest in all things musical. He was a familiar figure at the opera, and in his home life he always had much music. It was pleasant to be with him there, observe his love for music, and enjoy his unique and charming personality. His legion of friends and associates can do no more than cherish his memory and be glad that his long and busy life ended in a peace as beautiful as his beloved music.

Mr. Bonzano was elected a Member of the American Society of Civil Engineers on August 7th, 1872.

JOHN DOUGLAS FOUQUET, M. Am. Soc. C. E.*

Died September 18th, 1913.

John Douglas Fouquet was born at Plattsburg, N. Y., on August 1st, 1829. He received his early education from governesses and at the Parish School. When he was sixteen years old, he was enrolled at the Plattsburg Academy, where he received his preparatory training. He entered Rensselaer Polytechnic Institute in 1849, taking the course in Civil Engineering.

In 1852, at the end of the Spring term, Mr. Fouquet left Rensselaer to accept a position as Draftsman on stations and buildings with the Plattsburg and Caughnawaga Railroad, which later became the Plattsburg and Montreal Railroad, and is now a part of the Delaware and Hudson System. On May 1st, 1854, he became a member of the Engineer Corps of the Sunbury and Erie Railroad, now the Philadelphia and Erie Branch of the Pennsylvania Railroad, with headquarters at Williamsport, Pa. He was engaged first as Assistant to the Planetable Topographer on the preliminary and location surveys of the road and, on their completion, was retained, under Mr. Robert Ferris, Chief Engineer, and Col. Phaon Jarrett, Assistant Chief Engineer, as Head Draftsman on the Eastern Division of the road (Ridgway and Sunbury Railroad), on the preparation of plans for the stations, buildings, culverts, and seven large Howe truss bridges, each 1 000 ft. long, at various crossings of the West Branch of the Susquehanna River.

On account of the panic of 1857, work on the Sunbury and Erie Railroad was suspended for six months, and during this time Mr. Fouquet was engaged under the late P. P. Dickinson, M. Am. Soc. C. E., Chief Engineer, as Leveler on the preliminary and location surveys on a line of about 40 miles, between Dauphin and Landisburg, Pa., for the Sherman Valley and Broadtop Railroad, which road was projected in connection with the Broadtop Coal Mines.

When work on the Sunbury and Erie Railroad was resumed, he returned to that road, with headquarters at Lock Haven, Pa., remaining with the Company until the fall of 1860, when the line was acquired by the Pennsylvania Railroad, at which time Mr. Fouquet returned to Plattsburg, N. Y. During the summer of 1861 he was engaged by the State of New York to survey and map the State prison property at Dannemora, N. Y., and, in connection with this work, he designed a ventilating shaft for the iron mines within the enclosure of Clinton Prison.

* Memoir prepared by the Secretary from information on file at the Society House.

On November 18th, 1862, Mr. Fouquet entered the United States Navy as Clerk to Rear-Admiral Theodorus Bailey, commanding the East Gulf Blockading Squadron, on the flagship *Lawrence*, which was stationed at Key West, Fla., part of his duties consisting in bearing dispatches to and from the U. S. Consul at Havana, Cuba.

In May, 1864, he resigned from the Navy and was appointed to a position at the Brooklyn Navy Yard by Gideon Wells, the Secretary of the Navy. On his arrival in New York City, however, he was offered and accepted a more lucrative position with the Athens and Schenectady Railroad as Topographer in the field organization then being formed by that road, with headquarters at Athens, N. Y. In this position he was engaged on preliminary and location surveys, and, later, on construction, in charge of the Terminal Division, which included docks, bulkheads, passenger stations, as well as engine-houses, shops, tenements, etc., at Athens.

In the fall of 1866, Mr. Fouquet entered the employ of the Atlantic and Great Western Railroad as Chief of Topography, on the staff of Col. James Worrell, who was Chief Engineer of the Sir Morton Peto project for an air-line from New York City to Chicago, with headquarters at Harrisburg, Pa. The work consisted in closing up gaps between existing lines in New York, Pennsylvania, and Ohio. There were five engineering corps in the field between Lewisburg, Pa., and Greenville, Ohio. In the spring of 1867, however, the failure of Sir Morton Peto caused all work to be abandoned, and the various corps were left stranded in the oil regions of Pennsylvania.

Mr. Fouquet then became Topographer, under the late Oliver W. Barnes, M. Am. Soc. C. E., Chief Engineer, on the preliminary and location surveys for the Dutchess and Columbia Railroad, later known as the Newburg, Dutchess, and Connecticut, and now the Central New England Railroad. He was afterward made Division Engineer on the construction of the Western Terminal Division, with headquarters at Fishkill, N. Y., and later became Architect for the terminal and station buildings.

On the completion of this work, Mr. Fouquet engaged in the private practice of civil engineering and architecture, with an office at Fishkill, N. Y. He designed the building for the Fishkill High School, and was engaged in engineering and architectural work by the Dart Manufacturing Company in connection with a large woolen mill plant at Glenham, N. Y. He was also engaged on work for the Whiting Junction Railroad of Vermont, now a part of the Vermont Central System, one interesting feature of this work being the construction and installation of a pontoon draw in connection with the maintenance of the channel in Lake Champlain.

In the spring of 1871, Mr. Fouquet retired from private practice to accept a position as Engineer and Architect with Garner and Com-

pany, of New York City, which Company owned large cotton mills and print works at various places in New York, Pennsylvania, and Rhode Island. In this position he designed and superintended the construction of many mills, warehouses and tenements in New York State, as well as dams, reservoirs, and connections with existing railroad lines, together with the reconstruction and additions to various plants belonging to the Company. He also designed a Club House at Stapleton, S. I., and rebuilt a New York residence, for Mr. William T. Garner, the President of the Company.

While in this position, Mr. Fouquet designed the large warehouse at the corner of Worth and Hudson Streets, in New York City, which is still in use. At that time this building was second in height to the Western Union Building, then the tallest commercial building in the city.

In the fall of 1876, when the business portion of Fishkill, N. Y., was nearly wiped out by fire, Mr. Fouquet opened a branch office there, and designed stores, dwellings, bank buildings, etc. In 1882, he resigned his position with Garner and Company to accept an appointment as Chief of the Construction Department of the New York, West Shore and Buffalo Railway (later the West Shore Railway), with headquarters at Jersey City, N. J. The work included the design and construction of bulkheads, piers, transfer and ferry bridges in New York Harbor, etc., the offices being subsequently moved to New York City, and finally to Weehawken, N. J.

In the fall of 1883 the Company was placed in the hands of a Receiver. With a few others, Mr. Fouquet was retained and made Division Engineer of the Western Division, with headquarters at Frankfort, N. Y. He remained at that place until the completion of the extensive yards and shops in 1884, when he was transferred to Syracuse, N. Y., and placed in charge of the completion of more than 100 stations, freight-houses, etc., between Newburgh and Buffalo, N. Y. In the fall of 1884, he left Syracuse and made his headquarters at Weehawken, N. J. In 1885, work on the West Shore Railroad was entirely completed, and Mr. Fouquet returned to his home in Fishkill, N. Y. Within a week, however, he was recalled to prepare the plans and take charge of the construction of the Forty-second Street Terminal Station in New York City, which had been destroyed by fire. He also prepared the plans for the Company's terminal at Jay Street.

In 1886, the West Shore Railroad was leased by the New York Central and Hudson River Railroad, and Mr. Fouquet was transferred to the Grand Central Station and made Architect of the combined systems. In addition to his architectural work, Mr. Fouquet had charge of the surveys for a branch road from the West Shore Railroad at Saugerties, N. Y., to the Harding Hotel on the summit of the

Catskill Mountains, a distance of about 9 miles, the maximum grade being about 80 per cent. He also had charge of all architectural and construction work in connection with the depression of the tracks of the New York and Harlem Railroad between Mott Haven and Woodlawn Junction, the elevation of the tracks on the viaduct from the north end of the Fourth Avenue Tunnel to Mott Haven Junction, and the construction of the large storage yards and shops at Mott Haven.

On September 1st, 1893, Mr. Fouquet resigned his position with the New York Central and Hudson River Railroad Company to engage in private practice in New York City as Consulting Engineer and Architect. In this capacity he made the plans and estimates for the elimination of grade crossings for the City of New Bedford, Mass., designed the Fireboat Station at Battery Park, for the City of New York, and was associated with the R. P. and J. H. Staats Company in the design of the façades for the bulkheads and piers for the Cunard, White Star, and Wilson-Furness Steamship Lines, on West Street, New York City.

In 1900, Mr. Fouquet was obliged to give up his work on account of serious illness. On his recovery he again entered the employ of the New York Central and Hudson River Railroad, but in January, 1905, he was so seriously injured by an accident in one of the passenger elevators at the Grand Central Terminal that he retired from active work and returned to Fishkill, where he resided until his death.

Mr. Fouquet was engaged actively in the practice of his profession for a period of 53 years, and the fact that during that time he had had charge of millions of dollars worth of work, and had never been long without employment, was always a source of gratification to him. He had sustained at various times fractures of both arms, and through the improper bandaging of one such fracture, had since the age of twelve years been confined to the use of his left hand.

In his early youth he had developed artistic talent, and at odd times and for his own pleasure, he worked in both oils and water colors. His leisure was devoted to hunting and fishing, from which recreations he derived much pleasure.

On December 27th, 1864, Mr. Fouquet was married, at Athens, N. Y., to Miss Emma J. Leffingwell. He is survived by two sons, Louis Douglas Fouquet, Engineer of the Sewer Division of the Public Service Commission of the First District, State of New York, and Morton Leffingwell Fouquet, Engineer in Charge of the Department of Substructures of the Borough of Brooklyn, New York City.

He was a Member of U. S. Grant Post, G. A. R., No. 327, of Brooklyn, N. Y. From his youth he had been a member of the Protestant Episcopal Church, and had always taken an active interest in church work, having served for many years as Vestryman at St.

Stephen's Church, in New York City, and as Vestryman and Junior Warden of Old Trinity, in Fishkill, N. Y.

Mr. Fouquet was elected a Member of the American Society of Civil Engineers on June 3d, 1885.

JAMES CHARLES HAUGH, M. Am. Soc. C. E.*

Died July 6th, 1913.

James Charles Haugh, the son of Thomas and Jane Watts Haugh, was born in Cincinnati, Ohio, on March 23d, 1855.

His primary education was received in the public schools of Cincinnati. At an early age he entered the office of Gen. A. J. Hickentopper, then City Surveyor, but pursued his studies at the High School by a night course. After some years in the City Surveyor's office, during which he had earned promotion, he entered the service of the Portsmouth and Ohio Railroad, from which employment he shortly resigned to become Resident Engineer of the Cincinnati Southern Railroad, in charge of tunnel arching and grade construction. In this work he was associated with the late Col. George B. Nicholson, M. Am. Soc. C. E., who had been the friend of Mr. Haugh's brother. The association of Mr. Haugh and Col. Nicholson was intimate until the death of the latter.

In 1881 Mr. Haugh was sent by Col. Nicholson to the New Orleans and North Eastern Railroad and had charge, as Resident Engineer, of the construction of the Lake Pontchartrain Trestle (21½ miles long) which at that time was the longest trestle in the world. On the completion of the construction of the New Orleans and North Eastern Railroad, Mr. Haugh was placed in charge of Maintenance of Track, Bridges, and Buildings, in which capacity he served until his death.

Mr. Haugh was a Member and Past-President of the Louisiana Engineering Society, and also a Member of the American Railway Engineering Association.

His information on all matters pertaining to the maintenance of railways was thorough, and he was perhaps one of the best informed engineers in the United States on timber preservation.

Mr. Haugh had a unique personality. He possessed a shyness which bordered almost on diffidence, yet a latent force pervaded his every thought and undertaking. He was exceptionally charitable, his charity being of the unostentatious kind. His unfailing cheerfulness was in itself an inspiration to those with whom he came in contact.

* Memoir prepared by W. B. Gregory and J. F. Coleman, Members, Am. Soc. C. E.

It is difficult to express in words the affection in which Mr. Haugh was held by his associates. His circle of acquaintances was large, and every member of it feels a sense of personal loss in his death. Those who were privileged to know him well believe that the world is better by reason of his sojourn therein.

Mr. Haugh was elected a Member of the American Society of Civil Engineers on February 2d, 1909.

FRANCIS VALENTINE TOLDERVY LEE, M. Am. Soc. C. E.*

Died August 17th, 1913.

Francis Valentine Toldervy Lee, son of Francis V. T. Lee, of Shropshire, England, an Officer of the Queen's Own Light Infantry, was born at Winchester, England, on August 28th, 1870. He was educated at the Manchester Grammar School, at Manchester, England, and the College Communal, at Boulogne, France, and, in 1897, was graduated from Leland Stanford, Jr., University, with the degree of A. B. in Electrical Engineering.

In 1887, Mr. Lee went to Sherbrooke, Que., Canada, and for three years was engaged as Private Secretary to the Chief of Construction of the Canadian Pacific Railway. In 1890 he resigned this position in order to supplement with a more adequate technical training part of the education he had received abroad. After a visit to his home in England, he returned to New York City, where, in 1892, he entered the employ of the Manhattan Electric Light Company, as Assistant to the Superintendent, in order to test his liking for the work before specializing in Electrical Engineering.

In 1893 he entered Leland Stanford, Jr., University, and there met the late Dr. F. A. C. Perrine, then Professor of Electrical Engineering, which meeting resulted in one of the great friendships of Mr. Lee's life. As his Secretary and General Laboratory Assistant, he came intimately in contact with Dr. Perrine during his college life, and so strong was his influence that many of Mr. Lee's old friends often remarked on the little personal mannerisms which each had acquired unconsciously from the other.

Shortly after his graduation in 1897, Mr. Lee was appointed Assistant Engineer to Mr. John Martin, District Engineer for the Pacific Coast Department of the Stanley Electric Manufacturing Company. He rose rapidly in the service of this Company, being appointed District Engineer in 1898, Manager in June, 1899, and, in 1900, in addition to his position as Pacific Coast District Manager of the Stanley Electric Manufacturing Company and many other

* Memoir prepared by the Secretary from information supplied by A. H. Babcock, Cons. Elec. Engr., Southern Pacific Co., San Francisco, Cal.

Eastern electrical manufacturers, he was made Vice-President and General Manager of John Martin and Company, Electrical Engineers and Contractors. During this period he had direct supervision of the erection of many of the earlier lighting and power plants which, later, were absorbed by the Bay Counties Power Company and the Pacific Electric Railway Company.

In April, 1906, Mr. Lee severed his connection with John Martin and Company, but followed Mr. Martin's interests into the Pacific Gas and Electric Company, where he served successively as Assistant to the President, in charge of the Engineering and Electrical Departments, Chairman of the Engineering Committee, as well as Assistant General Manager in charge of and responsible for the construction and operation of the hydraulic developments of the Company.

In 1910, Mr. Lee resigned his position with the Pacific Gas and Electric Company, and until a few months before his death spent the time with his family at his old home in England and traveling on the Continent. He had returned to Victoria, B. C., Canada, which city he had intended to make his future home, only a few months before his death.

On September 27th, 1899, he was married to Edith K. Bonnallie, of Sherbrooke, Que., Canada, who, with two daughters, Ruth and Margaret, survives him.

Mr. Lee died before much of his work, particularly that of the last seven years, had time to demonstrate its real worth. In all his business life, his relations with the really big men with whom he worked brought a mutual confidence and personal regard which, in many cases, amounted to real affection. For the others, those of less caliber, he had a good-humored tolerance, although, at times, his path was made exceedingly rough.

His absolute faith in the kindliness of human nature was wonderful, for he had many rebuffs. They never embittered him, however, and he refused to believe any harm or evil of any one until he had absolute proof of it. Many times he was heard to say "'They say,' is a liar," and he lived up to this saying. Those who came intimately in contact with him knew the absolute integrity, the uprightness, and the sweet disposition of the man, and are thankful for their memory of him.

Mr. Lee's personal tastes were simple. The fine arts, of which he had a cultured enjoyment, appealed to him strongly. His reading covered a wide range, and, having leisure, he enjoyed his fine reference library to the full. A list of the works therein is an index of his versatility, and is a revelation even to his intimate friends.

At the time of his death, he was a Member of the American Society of Mechanical Engineers, the Institution of Electrical Engineers, the

American Institute of Electrical Engineers, the American Gas Institute, and the American Electrochemical Society. He was also a Member of Occidental Lodge, F. & A. M., of California Chapter, R. A. M., and of Golden Gate Commandery, K. T., all of San Francisco.

Mr. Lee was elected a Member of the American Society of Civil Engineers on February 1st, 1910.

WILLIAM NAPIER RADENHURST, M. Am. Soc. C. E.*

Died April 23d, 1913.

William Napier Radenhurst, the son of John and Mary Radenhurst, was born in Toronto, Ont., Canada, on November 5th, 1838. He attended the Rensselaer Polytechnic Institute during 1854, '55, and '56, and pursued studies in Civil Engineering. As a young man, Mr. Radenhurst was employed on the Grand Trunk Railway, and later traveled in New Zealand and New South Wales.

He was appointed Draftsman in the Department of Docks, New York City, by the late Gen. George B. McClellan, and served in that capacity, and as Surveyor and Inspector, until he resigned on January 1st, 1876. He was afterward connected with the Western Division of the New York State Canals, under the State Engineer, Robert Van Buren, M. Am. Soc. C. E., and Division Engineer Evershed. During this period he made surveys of Niagara Falls and vicinity, when the State took over the Park Reservation.

In 1883, Mr. Radenhurst became Assistant Engineer, under the late J. Nelson Tubbs, M. Am. Soc. C. E., Chief Engineer, of the Executive Board of the City of Rochester, N. Y., and retained that office under Emil Kuichling, M. Am. Soc. C. E.

He was appointed Water-Works Assistant Engineer on January 1st, 1900, under the City Engineer, Edwin A. Fisher, M. Am. Soc. C. E., which position he retained for eight years, when he was appointed Assistant Engineer in charge of Permits and Subways. He retired from active professional work on January 1st, 1910.

He was married in 1867 to Frances Hawksley, of Toronto, Ont., Canada, who survives him.

Mr. Radenhurst was a man of artistic tastes and had a wide acquaintance with literature. Although of a retiring disposition, he had many warm friends. He was fond of children, and, having none of his own, he and his wife reared and cared for a number from childhood to maturity.

Mr. Radenhurst was elected a Junior of the American Society of Civil Engineers on July 7th, 1875, and a Member on July 7th, 1880.

* Memoir prepared by John F. Skinner, M. Am. Soc. C. E.

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William P. Morse

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

VOL. XXXIX—No. 9

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November, 1913

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The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

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INSTITUTED 1852

PROCEEDINGS

This Society is not responsible for any statement made or opinion expressed in its publications.

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MINUTES OF MEETINGS

OF THE SOCIETY

Wednesday, October 15th, 1913.—For the minutes of the regular meeting of October 15th, 1913, which was held in New Orleans, La., see page 700.

Wednesday, October 15th, 1913.—An informal meeting was held at the Society House; Robert Ridgway, Director, Am. Soc. C. E., in the chair; and present, also, 194 members and 24 guests.

George A. Harwood, M. Am. Soc. C. E., Chief Engineer, Electric Zone Improvements, New York Central and Hudson River Railroad, presented a lantern slide description of the Grand Central Terminal work in New York City.

A vote of thanks to Mr. Harwood, proposed by Alfred Noble, Past-President, Am. Soc. C. E., was carried unanimously.

Adjourned.

November 5th, 1913.—The meeting was called to order at 8.30 P. M.; Vice-President J. Waldo Smith in the chair; T. J. McMinn, Assistant Secretary, acting as Secretary; and present, also, 193 members and 20 guests.

The minutes of the meetings of September 17th and October 1st, 1913, were approved as printed in *Proceedings* for October, 1913.

A paper entitled "Concrete Bridges: Some Important Features in Their Design", by Walter M. Smith, Sr., M. Am. Soc. C. E., and Walter M. Smith, Jr., Jun. Am. Soc. C. E., was presented by Mr. Walter M. Smith, Sr., and the subject was discussed by Messrs. C. E. Gregory, H. H. Quimby, A. C. Janni, Wilson F. Smith, and the author. The Assistant Secretary read a communication on the subject from S. W. Bowen, M. Am. Soc. C. E.

A paper by J. L. Van Ornum, M. Am. Soc. C. E., entitled "The Effect of Saturation on the Strength of Concrete", was presented by title, and communications on the subject from Messrs. E. A. Moritz, J. R. Worcester, Walter S. Wheeler, and Clifford Richardson, were read by the Assistant Secretary. The paper was discussed orally by H. H. Quimby, M. Am. Soc. C. E.

The Assistant Secretary announced the following deaths:

ERNEST PONTZEN, of Paris, France, elected Corresponding Member, January 5th, 1876; died October 13th, 1913.

LUTHER REESE ZOLLINGER, of Philadelphia, Pa., elected Member, March 6th, 1901; died October 21st, 1913.

HORACE GUY MERRICK, of La Crosse, Wis., elected Associate Member, May 7th, 1913; died October 30th, 1913.

Adjourned.

NEW ORLEANS MEETING.

October 15th, 1913.—The meeting was called to order at 8.15 P. M., in the Grunewald Hotel, New Orleans, La.; Vice-President J. Waldo Smith in the chair; Chas. Warren Hunt, Secretary; and present, also, about 150 members and guests.

Weston E. Fuller, M. Am. Soc. C. E., presented his paper entitled "Flood Flows," illustrating it by numerous stereopticon slides.

President Swain took the chair.

The Secretary read a discussion by Arthur E. Morgan, M. Am. Soc. C. E., and announced that he also had written communications on the subject from Messrs. E. Kuichling, Herbert E. Bellamy, E. F. Chandler, H. V. Hinckley, and Allen Hazen.

Messrs. Morris Knowles and Arthur E. Morgan discussed the paper orally. The other written discussions were not presented on account of lack of time.

George G. Earl, M. Am. Soc. C. E., delivered a very interesting talk on the Sewerage, Drainage, and Water-Works of New Orleans, which was illustrated by stereopticon slides.

The Secretary announced that the following members of the Society had been appointed by the Board of Direction as a Special Committee to draft A National Water Law: F. H. Newell, George G. Anderson, Charles W. Comstock, Clemens Herschel, W. C. Hoad, Robert E. Horton, John H. Lewis, Charles D. Marx, and Gardner S. Williams.

The Secretary also announced that the Board of Direction has appointed a Special Committee to Study the Question of Floods, Flood Prevention, and other allied subjects; that the Committee is not quite complete, and therefore that the names of the members cannot be announced at present.

Adjourned.

REPORT IN FULL OF FIRST SESSION, NEW ORLEANS MEETING

October 15th, 1913.—The meeting was called to order in the Gold Room of the Grunewald Hotel, New Orleans, La., at 10:30 A. M., by F. M. Kerr, M. Am. Soc. C. E., Chairman of the Local Committee of Arrangements.

There were present about 150 members and guests.

MR. KERR.—Ladies and gentlemen, and members of the American Society of Civil Engineers and of the Louisiana Engineering Society: As Chairman of the Local Committee of Arrangements, it is my very pleasant duty to announce the opening of this meeting of the American Society of Civil Engineers, and without further preamble, we will proceed to carry out the programme.

The first item on the programme should have been an address of welcome by His Excellency, Luther E. Hall, Governor of the State of Louisiana, but to our great regret, the Governor was called out of the city on extremely urgent business matters, of great importance to the State, and is, therefore, unable to be with us this morning. I am sure that he regrets it as much as we do.

The next in order in our great State, is our beloved Crescent City, and I know of no one who can better, more sincerely, more fully, and more quickly make all feel entirely at home with us than our popular Mayor, the Honorable Martin Behrman, whom I now have the pleasure of introducing to you.

MAYOR BEHRMAN.—Mr. Chairman, ladies and gentlemen, members of the American Society of Civil Engineers: It is unnecessary for me to tell you what distinguished pleasure it gives me this morning to welcome to our city the members of the American Society of Civil Engineers and their families. I always knew that a man, to be a Civil Engineer, naturally, of course, must be educated; he must be a level-headed man, and this is evidenced more especially to-day by the fact that so many of the members have brought their wives with them,

because I know from experience that, no matter how carefully we may draw our plans, the head of the household must sometimes be allowed a little liberty. So, I say to the engineers, so many of whom have brought their wives, that whatever plans have been made for their entertainment, I know will include and have the full approval of their entire families.

It is with peculiar delight that I welcome you here to-day, for the reason that we owe so much in this section to the brains of the members of your Profession and Society. We have a great number of the members of your Society here who have done a great deal to put this city in its present position. Our systems of sewerage and drainage and our levee system are all due to the intellects of the members of your organization. I am glad that you all are going to have an opportunity to see the results of some of the work of these engineers.

You will, of course, have an opportunity to inspect our magnificent harbor. You will see the long lines of great docks covered with steel sheds. You will see a practical belt railroad in operation. You will see our splendid filtration plant, clarifying the waters of the Mississippi River, which at one time was thought impossible. You will see our magnificent school buildings. You will see the wonderful docks at Port Chalmette, and the new roads and highways of the City of New Orleans. In fact, you will see so many things that will be of interest to the members of your Profession, that you will all be glad that you have come to New Orleans.

When I stand before you as the representative of this municipality, uttering these words of welcome, I know that the city has a well-earned and well-merited reputation to sustain for its hospitality, but in the use of the mere formal word of welcome, it does not mean the cold, chilly word "welcome" alone; when we say that we give to you the keys of our city it does not mean a superficial key presented to you; it means that it opens the hearts and homes of all our people to the stranger who comes this way.

In this city you will find much of interest to you, both of history and of tradition. The great wide street below this hotel practically divides the old from the new. Below Canal Street you will find scenes which remind you of Madrid and Paris, and above Canal Street you will see the live, hustling, bustling American city.

On Canal Street—I say this for the particular benefit of the ladies —you will find the most magnificent shopping district in this country.

Now, I know you have not come here to listen to a speech from me, but I want to say to you that I am proud of our city, and I want you to leave here, feeling pride in the things that have been done by the members of your Profession. You know that a great many people say we are too modest down here. I told the grain dealers yesterday

that a man who has been a candidate for public position several times cannot be accused of being very modest, because he has to get out and hustle, and ask people to vote for him, and that, you know, has a great tendency to remove any traces of modesty.

Of course, I know that you gentlemen of the Engineering Societies will not look at the many important works which have been carried on here, and which mean so much to this section of the country, from the business point of view, but you will look at them from the engineering standpoint, and see the wonderful results which have been accomplished by the engineers. You will learn that we have two sets of sewer systems, one for sanitary purposes and the other for taking care of the drainage of the city, and I know that the necessity for these will be explained to you by some of the members of your Society.

Again, I wish to say that it is my great pleasure and delight, this morning, on behalf of all the people of this city, to bid you a most hearty welcome.

Mr. Kerr.—Associated with the members of the American Society of Civil Engineers, is the Louisiana Engineering Society, and in our endeavors to welcome and entertain you as our guests, we have with us on the platform to-day the President of that Society, who will speak on its behalf. I have the pleasure of introducing Mr. Shaw, President of the Louisiana Engineering Society.

A. M. Shaw, M. Am. Soc. C. E.—Ladies and gentlemen and fellow-members: After those kind words of introduction from Mr. Kerr, I hardly have the face to start my remarks as I had intended, but must ask some kind and disinterested person to make a careful record of the time consumed by me, and compare it with the gentlemen who follow me, because the only source of friction at the many pleasant meetings which the Local Committee has had in preparing for this affair has been the insistent demand, that has been made and continuously impressed on me, that I should make my remarks brief, boil them down, make them short, and shorter, and I want a careful comparison made.

You have been welcomed to our city by his Honor, the Mayor, and it is now in order that you should be greeted by the local engineering society, as we are comparatively strangers, and among those present it might be well for some one to start introducing one another.

As for the Louisiana Engineering Society, I want to say that it was organized in 1898, and during its fifteen years of life, has experienced the usual ups and downs of an organization of that nature. It now has about 190 members, divided into grades corresponding approximately to those of the American Society of Civil Engineers; we also have resident and non-resident members, associates, and juniors, and a student membership, to which are eligible the members

of the senior classes in engineering in our Tulane University of New Orleans, and the State University at Baton Rouge.

The Louisiana Society numbers among its members, and especially among its past-presidents, engineers who have made their marks in the Profession. Now, I am going to take occasion to explain a predicament in which we find ourselves. We have an article in our Constitution which provides that no President may succeed himself in office, and this article the members of the Association have distorted into the view that no Past-President is eligible for re-election. The result is that we have exhausted all the available, or suitable, presidential timber, and, as the mill men down here say, when they have cut off all their long-leaf yellow pine, the mill is now working in loblolly, and that will explain how I came to be President.

We claim much credit for work that has been done by the Society in the past, and by various members of the Society in the past few years, for the betterment of conditions surrounding the Profession. Perhaps the most notable work was securing the enactment of a law regulating the practice of Civil Engineering by the State of Louisiana, the local society of engineers being largely responsible for it. A great deal has been said and written in adverse criticism of this law, many of the regulations of which are claimed to be irksome, but our only reply is that here in Louisiana it has been a success—not an unqaulified success—no one expected that, but a sufficiently pronounced success fully to justify its existence. Perhaps the greatest benefits which have been derived are not so much the fear of punishment for violations of the law, but that the general conditions of the engineeers themselves have been bettered; and I well remember the discussion that occurred at the time the law was being considered, and now see the betterment that has resulted from its operation. In these discussions, it has been evident to every one that there is a necessity for this among the better engineers, and this has established a code of ethics, not well-defined and uniform, but one that has tended to a better understanding among the members of the Profession.

In bringing this about, the Louisiana Engineering Society and its members deserve considerable credit for the work done along those lines; and, that being the case, I present to you a body of men who are with the members of the American Society of Civil Engineers in their efforts to raise the standards of the Profession and increase the esteem in which it is held by the public at large. I have pleasure in presenting to you the Louisiana Engineering Society.

Mr. Kerr.—The next item on our programme—I do not wish to inflict on you any remarks from the Chairman of the Local Committee of Arrangements, because I feel that everything that could be said, has been included in the remarks of Mr. Shaw—but we have with us one of the most prominent members of the Engineering Profession, and

I have pleasure in introducing to you a gentleman who is well known to almost all of you, Mr. Swain, President of the American Society of Civil Engineers.

George F. Swain, President, Am. Soc. C. E.—Your Honor, Mr. President of the Louisiana Engineering Society, Mr. Chairman of the Committee of Arrangements: On behalf of the American Society of Civil Engineers, which I have the honor to represent on this occasion, I tender you our most hearty thanks for your kind words of welcome. We are very glad indeed to be here, and we are glad that you are glad to see us. According to my experience, there is scarcely anything that is more instructive than travel. Not only does one meet new people, but the fact that he keeps his eyes open and observes what he really sees, necessarily gives him a broader point of view, makes him more modest, and less self-satisfied. After we have been accustomed at home for years to doing our work in our own way, until we finally come to think that is necessarily the best way, and that no improvements can be made, if we then go into another part of the country, and see other people doing that same work in perhaps a better way, or, at all events, in a different way, along lines that seem to be an improvement on our own method, and see them solving problems very different from those we have to face, and which we have never thought of, we must necessarily gain a great deal of information from the different points of view, and come to feel a little bit more modest, and, as I said, a little less self-satisfied. We must have a little more regard and appreciation for other people.

We have come here to this meeting, as I understand it, from distant parts of the country. Some of us from New England, with its rocky soil, where the principal crop is the ice crop, some of us from the far West with its boundless wheat fields, and the rest of us from the Southern portions of the country. We have come to this beautiful sunny southern land, with its rice fields, its plantations of sugar cane, its balmy breezes and all the other different conditions—the differences between this land and ours—and I think that we will all give more thought to these things, and to the realization of the great diversity of this great land of ours, the great diversity in its products, and we will be made to realize that this great country offers resources sufficient for almost every need of the people who inhabit it; sufficient not only for almost every need, but almost every luxury, and it must make us feel, therefore, that if we do not permanently remain a prosperous, contented, and happy people, it is not for any lack of physical resources with which it is endowed by the Creator, but it must be because we do not use those resources wisely, or because we perhaps do not take the proper point of view with reference to the duties of one man to another.

Then, there are other advantages in going from one part of the country to another, because of the opportunities afforded to learn to know the people in other sections. This diversity between the different parts of the land means some diversity in the physical characteristics, and diversities in the people, and I am sure that, for my part, I know nothing more beneficial than to travel to distant parts of the country, and to learn to know the people there. I wish we had more travel in our own country, and if I had my way, I would do something to see that every American should see his own country—the North, the South, the East, and the West—before going to foreign lands. Of course, we all realize that in every part of our country there are different points of view, different problems, and different necessities, and especially in forming our opinions on the various matters which we are asked to form an opinion on, we must do that justly.

We engineers represent a class of people who are concerned in dealing with the natural resources, making them available to man, but, in doing this work, two of the strongest aids to the engineer are the financier and the promoter. That combination is requisite for developing and making available the natural resources. When we come here from other parts of the country, we find that you in Louisiana have very different problems confronting you from those we have in the North. You have to control the great "Father of Waters", you have your problems of sewerage and drainage which are so much to you, and we shall study with great interest those problems presented to you here. I am sure that we shall go back to our own difficulties better able to solve the problems that we shall have, from a study of the means by which you have overcome the problems facing you.

I understand that you have great resources, great agricultural resources, and in addition to that, you have an untold supply of gas, great deposits of oil, salt, and sulphur, and probably other natural resources that I know nothing about. We shall pay much attention, and study as carefully as our limited time allows us what you have done in developing those resources.

I cannot forbear, in connection with this visit of the American Society of Civil Engineers to the South, from saying that it is of great personal interest to me, because my first engineering work was done in the South, in connection with the study of one of its great resources, not so great a resource in this State as in some of the other States, but still, a great resource in the South, and that is, its water power.

At that time, a great many years ago, as a young man, I came to know the South and to know the Southern people, and I came to love them—and I want to say that no one can know them without

loving them—and, therefore, this visit is, as I have said, of peculiar interest to me; ever since those days I have embraced every opportunity which presented itself to come to see them.

Now, your Honor, and the gentlemen who represent the Louisiana Engineering Society, again I thank you for your cordial words of welcome, and for the offer of the hospitality of this city—that well-known Southern hospitality—and I feel safe in saying that you could not have any more appreciative guests than we shall be.

Again, I thank you.

Mr. Kerr.—We have not with us to-day the first lady of the land, the wife of the President of the United States, but we have with us the first lady of the American Society of Civil Engineers, the wife of the esteemed President of that Society, and on behalf of the Louisiana Engineering Society, I take great pleasure in presenting to her this bunch of goldenrod.

Mrs. Swain.—Members of the Louisiana Engineering Society: I thank you.

Mr. Kerr.—If you all will pardon me, this comes a little late, but I have just received this telegram from his Excellency, Governor Hall:

"I regret very much my inability to attend the Convention of the American Society of Civil Engineers. I have asked Mr. Alexander to represent me."

I have also a letter that I think will please the members of the Society, from a very charming lady, Mrs. B. M. Harrod, the widow of Major B. M. Harrod, a former President of the American Society of Civil Engineers, which she asks me to read.

"1734 West Beach, Biloxi, Miss.,
"October, 1913.

"Mrs. B. M. Harrod sends greetings of love to The American Society of Civil Engineers, and regrets that absence from home will prevent her meeting them in person.

"I have not forgotten that you crowned me your Queen in Quebec. It was ever a source of joy and pride to both the Major and myself.

"May God bless, and prosper you in all your undertakings.

"Very truly yours,
"Mrs. B. M. Harrod."

Mr. Kerr.—Another announcement which I wish to make before we get to other parts of the programme is that to the members of the American Society of Civil Engineers are extended the courtesies of the Young Men's Gymnastic Club, the Chess, Checkers, and Whist Club, and the Southern Yacht Club, to which you all will be admitted on presentation of your badges.

I also have an invitation from the Tulane University of Louisiana at New Orleans, on behalf of the Board of Administrators and Faculty.

Next on the programme is an address by John F. Coleman, M. Am. Soc. C. E., one of our prominent engineers, who will describe the local topographical peculiarities in New Orleans.

Mr. Coleman then addressed the meeting.

Mr. Kerr.—It now gives me great pleasure, and I know it will be yours, to introduce Arsène Perrilliat, M. Am. Soc. C. E., who will tell you something about Mississippi River control.

Mr. Perrilliat then addressed the meeting.

Mr. Kerr.—I now have pleasure in introducing to you Mr. Alexander, President of the Conservation Commission of the State of Louisiana, who will represent the Governor and say something to you in his name.

Mr. Alexander.—Mr. Chairman, ladies and gentlemen, and members of the American Society of Civil Engineers: I first wish to apologize for my apparent neglect in not being here sooner, and wish to state that only a few moments ago I received the Governor's telegram requesting that I appear before you and express his regrets.

I want to say to you on behalf of the Governor that he is deeply interested in the engineering problems that affect the State of Louisiana, and he is deeply appreciative that this meeting is being held in the principal city in the State of Louisiana, and on his behalf I wish you all a very cordial and hearty welcome, and with the whole people of the State of Louisiana, I sincerely trust that your stay in our midst will be both profitable and pleasant.

It would be probably not inappropriate if I should say to you briefly something of the resources of Louisiana. I should feel particularly inclined to do that, as President of the Conservation Commission of the State of Louisiana, the Commission which has charge of all the State's natural resources, and I am always glad to exploit them, and to tell those who come into our midst, whenever I have an opportunity, something of the wonderful riches of the State of Louisiana.

These resources in themselves have brought up some great problems in engineering, problems in which I am sure you will all be interested. For instance, take the great sulphur mines of Calcasieu Parish, the greatest sulphur deposit in all the world, where the sulphur is being mined from the earth 99.9% pure, and where there is now something like $12 000 000 worth of sulphur pumped out of the ground lying in bins on top of the earth ready for marketing. That mine has presented one of the greatest problems in engineering, and before the people who now operate it took hold of it, many firms had "gone broke" in attempting to solve it. I understand that the mine was originally owned by some people in France, who attempted to reach the sulphur deposit by sinking shafts, but owing to the shifting nature of the soil, quicksands, etc., they were unable to do so, and

finally a plan was invented of pumping hot water down into the bowels of the earth, melting the sulphur, which was brought up in liquid form, run into bins, where it solidified, and became great mountains of sulphur.

In the northern part of the State, we have those wonderful oil fields of Caddo Parish, probably the greatest oil fields in the United States, if not in the world, which are yielding something like one million barrels of oil per month—oil of the very finest grade. These oil fields have also provided some great engineering problems. Recently, a well was brought in which yielded something like twenty-five thousand barrels of oil per day; that well caught fire, and it was a great feat of engineering to put it out. It ran wild for something like fifteen or twenty days, and cost the owners something like twenty-five thousand dollars per day in addition to the expense of extinguishing the fire. I believe that the only process that was found practicable was to assemble about fifty steam boilers around the well and simply drown it with steam. In this way it was finally brought under control.

Another of the great resources of Louisiana is the great natural gas fields, also in Caddo Parish, and producing now, for commercial and domestic purposes, something like two hundred million cubic feet of gas per day. There was a well in that field which had run wild and had been burning for 6 years; this well was a blazing, raging torrent of gas and water, and had formed an immense crater around it. It was considered so great a problem in this country that Government experts who had visited and inspected it, commented on it, and it was held to be a great disgrace that the State of Louisiana should permit this enormous waste. It was estimated that the well was wasting, or exhausting, something like forty or fifty million cubic feet of gas per day, and that before the final closing something like two hundred million cubic feet of gas had gone to waste. The Conservation Commission of Louisiana, through its Engineering Department, took hold of this proposition, and, with the co-operation of the owners, went to work to stop it. It had been estimated that the cost of closing the well would be anywhere from twenty-five thousand to one hundred and fifty thousand dollars. As I said, when we took hold of the problem, there was an immense crater surrounding the well, and by boring it, we discovered where the trouble existed, and found that nothing could be done looking to filling the crater and thus stopping the flow of gas. Then the engineers evolved the idea of putting down a relief well, seventy-five feet away; this well was sunk down to the stratum from which the gas was coming in the original well. After reaching that stratum and making their investigation, the engineers decided that the only thing to do was to pump water down into it, and finally force an entrance between the two wells.

After pumping something like four or five million gallons of water into the relief well, they finally drowned out the wild well, and the entire expense of the solution of this problem was something less than six thousand dollars.

There are many other problems from an engineering standpoint in which we are all interested. We have the wonderful salt deposits of Iberia Parish, which I understand you are to visit. This is probably the greatest salt deposit on the Western Hemisphere. It exists in a salt marsh in the southern portion of Iberia Parish, on the Gulf Coast, and the salt which comes from it is 99.8% pure.

And then we have the wonderful waterways of Louisiana. Of course, the problem of the Mississippi River, which has been briefly explained to you, I understand, by Mr. Perrilliat, is probably one of the greatest confronting the Engineering Profession to-day, and I need not touch upon it.

The reclamation problem, of draining our wet lands and bringing them into cultivation, is another of the vast problems confronting us, and I am glad to say that this is being solved by men of your profession, and thousands of acres of the very richest land on earth are annually being brought into cultivation. These lands are capable of growing anything that grows.

Off our southern coast, we have another great resource, the great game preserve. It is near Avery's Island, which contains the salt mines you are to visit. This is the greatest game preserve in the world, protected under the laws of the State of Louisiana, and comprises something like one hundred thousand acres, set aside as a resting and breathing place for wild fowl of all kinds.

Another of our great resources is the immense oyster beds, probably the greatest in size in the United States, with something like four hundred thousand acres available for the propagation of the finest oysters in the country; and these oysters are going to continue to grow and develop the value of these lands very much in the future, for the State of Louisiana. These are only a few of the many advantages we have. We have the most delightful climate in the world, cool and pleasant in the summer, warm and delightful in the winter; there is hardly a month in which you cannot grow something in these wonderfully fertile lands of ours; of these and the many advantages to be gained by those who come to make their homes among us, we want you to know.

On behalf of the Governor of the State, I bid you a very cordial welcome to the State of Louisiana.

Mr. Kerr.—Gentlemen, I have here a resolution which I have been asked by J. A. Ockerson, Past-President, Am. Soc. C. E., to present in his behalf:

"RESOLVED: That we extend our most cordial greetings to Mrs. Harrod, and express our deep appreciation of her graceful recognition of our presence in this, her home city."

The resolution was seconded and carried unanimously.

A MEMBER.—I move that a telegram be transmitted to Mrs. Harrod conveying this resolution.

This motion was duly seconded and adopted.

Adjourned.

EXCURSIONS AND ENTERTAINMENTS
NEW ORLEANS MEETING

The arrangements for the Excursions and Entertainments were in the hands of the following Committee:

FRANK M. KERR, *Chairman*,
J. F. COLEMAN, ARSÈNE PERRILLIAT,
E. L. JAHNCKE, A. M. SHAW,
SIDNEY F. LEWIS, W. H. WILLIAMS,
A. M. N. BLAMPHIN.

Wednesday, October 15th, 1913, 2 P. M.—All those in attendance were taken by automobile on a long trip through the city, which occupied the whole afternoon.

Thursday, October 16th.—The members and their guests were taken on a trip in New Orleans Harbor in the Steamer *St. James*. This boat, a typical Mississippi steamer, with a large party on board, left the landing near the head of Canal Street at 10 A. M. and steamed to all parts of the harbor. Lunch was served on board. At the head of Carrollton Avenue the party landed, and in automobiles visited and inspected the Water Filtration plant, Drainage Pumping Stations, and other engineering works, returning to the hotel at 5.30 P. M.

8 P. M.—There was a large attendance at a "Smoker" given in the Hotel Grunewald.

Friday, October 17th.—At 11 A. M. the party, in small groups, for which guides were provided, visited the old French quarter of the city.

2.30 P. M.—In the afternoon a Garden Party at the grounds of the Country Club was attended by a large number of members and guests.

8.30 P. M.—A Dinner Dance was given in the evening in the roof garden of the Hotel Grunewald.

Saturday, October 18th.—The day was devoted to an excusion to Avery Island and the Salt Mines near New Iberia, and was enjoyed by a large number of members and guests. At 8 A. M. the party was conveyed in special cars of the New Orleans Railway and Light Company, to the Southern Pacific Ferry at the head of Esplanade Avenue, and crossed the river to Algiers. There, by the courtesy of the

Southern Pacific Railroad. Mr. Guy Hopkins, General Superintendent, a special train was provided. Through the courtesy of General Dudley Avery, of the Avery Rock Salt Mining Company, and Messrs. E. A. McIlhenny, E. A. Hill, and Sidney Crawford, connected therewith, every facility was afforded for a complete inspection of the salt mines. Luncheon was served. The return to New Orleans was somewhat delayed, the party arriving there about 11.30 P. M.

9.45 P. M.—A number of members took advantage of the opportunity to visit the Panama Canal, sailing for the Isthmus on one of the United Fruit Company's steamers.

Attendance

At this meeting of the Society, the first held outside of New York City, 478 persons were present, of which 121 were connected with the Society, 86 were members of the Louisiana Engineering Society, and 271 were guests.

ANNOUNCEMENTS

The House of the Society is open from 9 A. M. to 10 P. M., every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

FUTURE MEETINGS

December 3d, 1913.—8.30 P. M.—A regular business meeting will be held, and two papers will be presented for discussion, as follows: "Coal Piers on the Atlantic Seaboard," by J. E. Greiner, M. Am. Soc. C. E., and "Topographical Surveys Made by the American Section of the International Boundary Commission, United States and Mexico," by W. W. Follett, M. Am. Soc. C. E.

These papers were printed in *Proceedings* for October, 1913.

December 17th, 1913.—8.30 P. M.—At this meeting two papers will be presented for discussion, as follows: "Storage to be Provided in Impounding Reservoirs for Municipal Water Supply", by Allen Hazen, M. Am. Soc. C. E.; and "The Depreciation of Public Utility Properties as Affecting Their Valuation and Fair Return," by John W. Alvord, M. Am. Soc. C. E.

These papers are printed in this number of *Proceedings*.

January 7th, 1914.—8.30 P. M.—This will be a regular business meeting. A paper by A. H. Sabin, Assoc. M. Am. Soc. C. E., entitled "Painting Structural Steel: The Present Situation," will be presented for discussion.

This paper is printed in this number of *Proceedings*.

ANNUAL MEETING

The Sixty-first Annual Meeting will be held at the Society House, on Wednesday and Thursday, January 21st and 22d, 1914. The arrangements for the Annual Meeting have been placed in the hands of the following committee: Messrs. Robert Ridgway, Henry W. Hodge, and Chas. Warren Hunt. The Business Meeting will be called to order at 10 o'clock on Wednesday morning. The Annual Reports will be presented, officers for the ensuing year elected, members of the Nominating Committee appointed, Reports of Special Committees presented for discussion, and other business transacted.

SPECIAL MEETINGS FOR TOPICAL DISCUSSION

On the two days immediately following the Annual Meeting, three meetings of the Society will be held, at which the subject for discussion will be "Road Construction and Maintenance."

The meetings will be held as follows:

First Meeting, Friday, January 23d, 1914.—10 A. M.—The following sub-division of the subject will be discussed:

(1) "Engineering Organizations for Highway Work."

Second Meeting, Friday, January 23d, 1914.—2 P. M.—The following sub-division of the subject will be discussed :

(2) "Factors Limiting the Selection of Materials and of Methods in Highway Construction."

Third Meeting, Saturday, January 24th, 1914.—10 A. M.—The following sub-division of the subject will be discussed :

(3) "Equipment and Methods for Maintaining Bituminous Surfaces and Bituminous Pavements."

SEARCHES IN THE LIBRARY

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

In reference to this work, the Appendices* to the Annual Reports of the Board of Direction for the years ending December 31st, 1906, and December 31st, 1910, contain summaries of all searches made to date.

PAPERS AND DISCUSSIONS

Members and others who take part in the oral discussions of the papers presented are urged to revise their remarks promptly. Written communications from those who cannot attend the meetings should be sent in at the earliest possible date after the issue of a paper in *Proceedings.*

All papers accepted by the Publication Committee are classified by the Committee with respect to their availability for discussion at meetings.

Papers which, from their general nature, appear to be of a character suitable for oral discussion, will be published as heretofore in

* *Proceedings*, Vol. XXXIII, p. 20 (January, 1907); Vol. XXXVII, p. 28 (January, 1911).

Proceedings, and set down for presentation to a future meeting of the Society, and on these, oral discussions, as well as written communications, will be solicited.

All papers which do not come under this heading, that is to say, those which from their mathematical or technical nature, in the opinion of the Committee are not adapted to oral discussion, will not be scheduled for presentation to any meeting. Such papers will be published in *Proceedings* in the same manner as those which are to be presented at meetings, but written discussions, only, will be requested for subsequent publication in *Proceedings* and with the paper in the volumes of *Transactions*.

The Board of Direction has adopted rules for the preparation and presentation of papers, which will be found on page 429 of the August, 1913, *Proceedings*.

LOCAL ASSOCIATIONS OF MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

San Francisco Association

The San Francisco Association of Members of the American Society of Civil Engineers holds regular bi-monthly meetings, with banquet, and weekly informal luncheons. The former are held at 6 P. M., at the Palace Hotel, on the third Friday of February, April, June, August, October, and December, the last being the Annual Meeting of the Association.

Informal luncheons are held at 12.15 P. M. every Wednesday, and the place of meeting may be ascertained by communicating with the Secretary of the Association, E. T. Thurston, Jr., M. Am. Soc. C. E., 713 Mechanics' Institute, 57 Post Street.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in San Francisco, and any such member will be gladly welcomed as a guest.

(Abstract of Minutes of Meetings)

August 15th, 1913.—The meeting was called to order; Vice-President C. H. Snyder in the chair; E. T. Thurston, Jr., Secretary; and present, also, 46 members and guests.

Messrs. M. C. Couchot, V. H. Poss, and L. H. Nishkian, of the Committee on the Building Ordinance of San Francisco and Its Enforcement, presented certain conclusions arrived at by that Committee.

The subject was discussed by Messrs. A. L. Bobbs, J. B. Leonard, R. S. Chew, C. E. Grunsky, H. D. Dewell, C. H. Snyder, L. E. Hunt, A. Judell, and E. T. Thurston, and, on motion, the Committee was directed to make a careful, detailed study of the engineering sections of the Ordinance and report its recommendations at the October meeting.

Adjourned.

October 17th, 1913.—The meeting was called to order; President Wing in the chair; E. T. Thurston, Jr., Secretary; and present, also, 57 members and guests.

A list of suggestions for increasing the scope and usefulness of the Engineering Library of the Mechanics' Institute, submitted as having had the approval of the Pacific Association of Consulting Engineers, was endorsed by the meeting, and the Secretary was instructed to transmit copies of the same to the local societies of mining, mechanical, and electrical engineers.

At the completion of the business meeting, the members arose and remained standing out of respect to the memory of the late Arthur L. Adams, M. Am. Soc. C. E., a Past-President of the Association and one of its founders, while President Wing made a few appropriate remarks.

After a protracted discussion as to how far and in what manner the Association might proceed in making suggestions as to the Amendment of the Building Ordinance of San Francisco, the conclusion was reached that, though the Association might not act officially on any proposed amendments, discussion of the subject might be undertaken, and that thereafter any member or group of members, individually or collectively, might publish the conclusions arrived at for the benefit of the public.

Messrs. M. C. Couchot and L. H. Nishkian, of the Association's Committee on the Building Ordinance, presented the Committee's suggestions to the meeting, and these were discussed in detail by Messrs. H. J. Brunnier, H. D. Dewell, R. S. Chew, Charles Derleth, Jr., C. W. Wing, W. L. Huber, A. V. Saph, and W. J. Miller.

Adjourned.

Colorado Association

The meetings of the Colorado Association of Members of the American Society of Civil Engineers are held on the second Saturday of each month, except July and August. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary, Roger W. Toll, Jun. Am. Soc. C. E., 700 Tramway Building, Denver, Colo. The meetings are usually preceded by an informal dinner. Members of the American Society of Civil Engineers will be welcomed at these meetings.

Weekly luncheons are held on Wednesdays, and, until further notice, will take place at the Colorado Traffic Club.

Visiting members are urged to attend the meetings and luncheons.

(Abstract of Minutes of Meeting)

October 11th, 1913.—The meeting was called to order; Vice-President E. F. Vincent in the chair; Roger W. Toll, Secretary; and present, also, 10 members and 5 guests.

The minutes of the meeting of September 13th, 1913, were read and approved.

A paper by Leonard Lundgren, Assoc. M. Am. Soc. C. E., on the "Organization and Conservation Policy of the United States Forest

Service," was presented by the author, and the subject was generally discussed by others present.

Leonard Metcalf, M. Am. Soc. C. E., addressed the meeting in regard to the recent activities and matters now under discussion by the American Society of Civil Engineers.

Adjourned.

Atlanta Association

On March 14th, 1912, the Atlanta Association of Members of the American Society of Civil Engineers was organized, with the following officers: Arthur Pew, President; William A. Hansell, Jr., Secretary; and Messrs. James N. Hazlehurst and B. M. Hall, Members of the Executive Committee. The Association will hold its meetings in the house of the University Club.

Philadelphia Association

At its meeting of June 4th, 1913, the Board of Direction of the Society considered and approved the proposed Constitution of the Philadelphia Association of Members of the American Society of Civil Engineers.

Portland, Ore., Association

On June 18th, 1913, the Portland, Ore., Association of Members of the American Society of Civil Engineers was organized with the following officers: E. G. Hopson, President; W. S. Turner, First Vice-President; D. D. Clarke, Second Vice-President; G. B. Hegardt, Treasurer; and Charles J. McGonigle, Secretary.

Seattle Association

On June 30th, 1913, the Seattle Association of Members of the American Society of Civil Engineers was organized with the following officers: Samuel H. Hedges, President; Ernest B. Hussey, Vice-President; and Joseph Jacobs, Secretary-Treasurer.

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms, and at all meetings:

American Institute of Mining Engineers, 29 West Thirty-ninth Street, New York City.

American Society of Mechanical Engineers, 29 West Thirty-ninth Street, New York City.

Architekten-Verein zu Berlin, Wilhelmstrasse 92, Berlin W. 66, Germany.

Associação dos Engenheiros Civis Portuguezes, Lisbon, Portugal.

Australasian Institute of Mining Engineers, Melbourne, Victoria, Australia.

Boston Society of Civil Engineers, 715 Tremont Temple, Boston, Mass.

Brooklyn Engineers' Club, 117 Remsen Street, Brooklyn, N. Y.

Canadian Society of Civil Engineers, 413 Dorchester Street, West, Montreal, Que., Canada.

Civil Engineers' Society of St. Paul, St. Paul, Minn.

Cleveland Engineering Society, Chamber of Commerce Building, Cleveland, Ohio.

Cleveland Institute of Engineers, Middlesbrough, England.

Dansk Ingeniorforening, Amaliegade 38, Copenhagen, Denmark.

Engineers' and Architects' Club of Louisville, Ky., 303 Norton Building, Fourth and Jefferson Streets, Louisville, Ky.

Engineers' Club of Baltimore, Baltimore, Md.

Engineers' Club of Minneapolis, 17 South Sixth Street, Minneapolis, Minn.

Engineers' Club of Philadelphia, 1317 Spruce Street, Philadelphia, Pa.

Engineers' Club of St. Louis, 3817 Olive Street, St. Louis, Mo.

Engineers' Club of Toronto, 96 King Street, West, Toronto, Ont., Canada.

Engineers' Society of Northeastern Pennsylvania, 415 Washington Avenue, Scranton, Pa.

Engineers' Society of Pennsylvania, 219 Market Street, Harrisburg, Pa.

Engineers' Society of Western Pennsylvania, 2511 Oliver Building, Pittsburgh, Pa.

Institute of Marine Engineers, 58 Romford Road, Stratford, London, E., England.

Institution of Engineers of the River Plate, Buenos Aires, Argentine Republic.

Institution of Naval Architects, 5 Adelphi Terrace, London, W. C., England.

Junior Institution of Engineers, 39 Victoria Street, Westminster, S. W., London, England.

Koninklijk Instituut van Ingenieurs, The Hague, The Netherlands.

Louisiana Engineering Society, 321 Hibernia Bank Building, New Orleans, La.

Memphis Engineering Society, Memphis, Tenn.

Midland Institute of Mining, Civil and Mechanical Engineers, Sheffield, England.

Montana Society of Engineers, Butte, Mont.

North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne, England.

Oesterreichischer Ingenieur- und Architekten-Verein, Eschenbachgasse 9, Vienna, Austria.

Pacific Northwest Society of Engineers, 803 Central Building, Seattle, Wash.

Rochester Engineering Society, Rochester, N. Y.

Sachsischer Ingenieur- und Architekten-Verein, Dresden, Germany.

Sociedad Colombiana de Ingenieros, Bogota, Colombia.

Sociedad de Ingenieros del Peru, Lima, Peru.

Societe des Ingenieurs Civils de France, 19 Rue Blanche, Paris, France.

Society of Engineers, 17 Victoria Street, Westminster, S. W., London, England.

Svenska Teknologforeningen, Brunkebergstorg 18, Stockholm, Sweden.

Tekniske Forening, Vestre Boulevard 18–1, Copenhagen, Denmark.

Western Society of Engineers, 1737 Monadnock Block, Chicago, Ill.

ACCESSIONS TO THE LIBRARY

(From October 2d to November 3d, 1913)

DONATIONS*

DESIGN OF PLATE GIRDERS.

By Lewis E. Moore, Assoc. M. Am. Soc. C. E. Cloth, 9½ x 6¼ in., illus., 8 + 285 pp. New York and London, McGraw-Hill Book Company, Inc., 1913. $3.00.

This volume, it is stated, is the outcome of the author's practical experience in bridge design and construction and as a teacher of the subject at the Massachusetts Institute of Technology. In his work, he has found, the preface states, that students as a rule have few ideas about designing and designs, and his aim in this book has been to explain clearly and in detail the reasons underlying a design, to show the assumptions made in given cases, and to give, as far as possible, alternative methods; in fact, to develop the ability of the student in order that he may be able to make an intelligent choice among various methods. The first two chapters, on stresses and riveting, have been made purposely short, it is stated, the treatment of the latter subject, however, differing somewhat from that usually given. The theory of plate girder design has been discussed in detail, it is further stated, and detailed designs of two different plate girders have been worked out with careful discussion of each point as it arises, railroad bridges being used. The principles developed in these designs, the author states, are of general application and can easily be extended to architectural work. The specifications of the New York, New Haven and Hartford Railroad have been used as a basis in these designs and are discussed in detail. Box girders are similarly worked out, it is stated, using a fixed load and without any specifications, the material on deflections, which is by Professor W. H. Lawrence, of the Massachusetts Institute of Technology, never before having appeared for general distribution. The chapter on Shop Hints is by John C. Moses, M. Am. Soc. C. E., and has been incorporated, it is said, to give the student ideas as to cost and shop possibilities. Tables are also included which the author hopes will be of aid to the practicing engineer in the design of plate girders by approximate and exact methods. The Contents are: Stresses in Plate Girders; Rivets; Theory of Plate Girders; Design of Through Plate Girder; Deck Plate Girder Design; Box Girders; Shop Hints for Structural Draftsmen; General Specifications for Steel Railroad Bridges; Conventional Signs; Tables; Index; Index to Specifications; Index to Tables.

THE ARCHITECTS' DIRECTORY AND SPECIFICATION INDEX FOR 1913-14

Containing a Complete List of the Architects of the United States and Insular Possessions, Canada, Cuba, and Mexico; Classified by States and Towns; Landscape and Naval Architects of the United States and Canada, etc.; A Specification Index of Prominent Dealers and Manufacturers of Building Materials and Appliances. Tenth Edition. Cloth, 10¼ x 7 in., 204 pp. New York, The William T. Comstock Company, 1913. $3.00.

In addition to the above information other important material is included in this book, namely, alphabetical lists of periodicals devoted to the interests of architecture and building, with names of publishers and subscription prices; architectural schools in the United States; architectural societies and organizations of the world, with names and addresses of their officers; and names and addresses of architects of Boards of Education, and of the Building Departments, in the principal cities of the United States and Canada. The professional codes adopted by the American Institute of Architects and the Province of Quebec Association of Architects, are also included, and under the Classified List of Architects are given the names and addresses of the officers of the State Boards of Examiners of Architects of the various States. For this, the tenth edition, a careful recompilation of the entire list has been made, the names and addresses, it is stated, having been checked by correspondence, the aim being to obtain an accurate list even at the expense of omitting the names of architects and firms which could not be verified.

* Unless otherwise specified, books in this list have been donated by the publishers.

THE ROLLING MILL INDUSTRY:

A Condensed General Description of Iron and Steel Rolling Mills and Their Products. By F. H. Kindl. Cloth, 9¼ x 6¼ in., illus., 76 pp. Cleveland, Ohio, The Penton Publishing Company, 1913. $2.00.

This book, the preface states, contains a summary of American rolling mill practice, the development of which is traced from its beginning to the present day. The author has also attempted, it is further stated, to define more closely the various kinds of mills and their products. Charts are given which show graphically the production of semi-finished and finished products and which represent modern practice at some of the largest open-hearth plants and rolling mills. Other charts are included which illustrate the quantities of material charged and produced in making one ton of pig iron; the distribution and production of iron and steel in 1907 and 1911; the conversion of pig iron into the various finished products, etc. A table is also given showing the comparison of the general fundamental factors dictating the production of pig iron in the United States, Germany and Great Britain, with particular reference to the Pittsburgh district of the United States, the Rheinland-Westfalia district of Germany, and the Cleveland district of Great Britain. The Chapter headings are: Historical; Classification of Rolling Mills; Finished Products; The Wire Industry; Tube and Pipe Industry; Tin and Terne Plate Industry; Statistical; Index.

UNDERGROUND WATERS FOR COMMERCIAL PURPOSES.

By Frank L. Rector. Cloth, 7¾ x 5 in., illus., 5 + 98 pp. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Limited, 1913. $1.00.

The subject of waters for commercial purposes, the author states, has heretofore received little attention, the available published material being devoted to considerations of waters for industrial uses and for municipal and public supplies. It has been his aim, therefore, in this book, to discuss in detail the question of bottled or mineral waters for drinking and domestic uses, their sources, properties, etc., a bibliography of the subject also being included. The Chapter headings are: Introduction; Source of Water; Ground Water; Distribution and Properties of Water; Springs; Wells; Watershed; Mineral Water; Chemical Examination; Bacteriological Examination; Microscopical Examination; Appendix: Useful Rules and Tables; Bibliography; Index.

ALTERNATING CURRENTS AND ALTERNATING CURRENT MACHINERY.

By Dugald C. Jackson, M. Am. Soc. C. E., and John Price Jackson. New Edition, Rewritten and Enlarged. Cloth, 9 x 6 in., illus., 9 + 968 pp. New York, The Macmillan Company, 1913. $5.50.

The first edition of this book was published in 1896. The present edition is said to have been entirely rewritten and greatly extended in order to bring the subject-matter up to the requirements of present-day teaching, the aim of the authors being to set forth the best treatment of each of the problems of alternating currents, together with the best literature and practice in connection with the subject. It is hoped that the book will be found valuable as a textbook as it is stated to cover the ground for a fairly complete course in the essential elements of alternating currents and their applications to machinery, as well as instruction in the electrical transmission of power. It is also intended as a reference book in respect to the principles used in the numerous modern applications of alternating currents to practical purposes. The phraseology is simple, it is stated, and follows standard practice. Mathematics have been avoided as far as possible in the text, and numerous examples are given to illustrate methods of utilizing the principles discussed, as well as numerous references to correlated literature. The Contents are: The Voltage Developed by Alternators; Elementary Statements Concerning Transformers and Measuring Instruments; Armature and Field Windings for Alternators; Self-Induction, Electrostatic Capacity, Reactance and Impedance; The Use of Complex Quantities Extended; Solution of Circuits; Power; Polyphase Circuits and the Measurement of Power Therein; Hysteresis and Eddy Current Losses; Mutual Induction; Synchronous Machines; Asynchronous Motors and Generators; Self-Inductance, Mutual Inductance, and Electrostatic Capacity of Parallel Wires; Index.

THE PANAMA GUIDE.

By John O. Collins. Cloth, 9 x 6 in., illus., 326 pp. Quartermaster's Department, Mount Hope, C. Z., I. C. C. Press, 1912. $1.35. (Donated by the Author.)

In the Introduction it is stated that this book contains answers to most of the questions which the author has been asked during the last four years in regard to Panama and the Panama Canal. He includes descriptions of the country and cities, its history, both ancient and modern, its customs, flora, meteorology, etc.; histories and descriptions of the Panama Canal and Panama Railroad; Government regulations as to postage and customs; the various treaties; Acts of Congress in relation to the Panama Canal; a census of the Canal Zone, etc. The Contents are: The Master Builder; Frcm Colon to Panama; The Panama Canal; Panama Railroad; History of Panama; Panama To-Day; City of Panama; Old Panama; Miscellaneous; Index.

STEEL DESIGNING (STRUCTURAL ENGINEERING, BOOK THREE).

By Edward Godfrey, M. Am. Soc. C. E. Leather, $6\frac{3}{4}$ x $4\frac{1}{4}$ in., illus., 492 pp. Pittsburgh, The Author, 1913. $2.50.

The keynote of this book, the author states, is sound engineering in every detail of steel design, the book being intended for use by all classes of men who have to do with structural steel. For the student, the principles of correct design in steel work are said to be emphasized and exemplified; for the inspector in mill and shop, the principles of correct manipulation are laid down; for the draftsman, standard and economic and consistent details are defined; for the college instructor, practical methods are set forth; and for the designing and consulting engineer, errors are pointed out. Much emphasis, it is stated, is placed on the importance of details and of simple and rational methods, and also on the waste of material. Errors of design are noted, and numerous examples of designs in various classes of steel construction are also included. The Contents are: The Working of Iron and Steel; The Preservation of Iron and Steel; Some Notes on Structural Detail Drawing; Some Notes on Detail Designing; Notes on Bridge Design; Notes on Building Design; Mill Building Design; The Design of Beams and Girders; Designing of Tension Members; The Strength of Compression Members; Designing of Compression Members; Rivets and Riveted Connections; End Connections of Tension Members; End Connection of Compression Members; Splices: Pins; Loads and Unit Stresses; Estimating Weights; Shear; Camber; Curvature; Grade; Provision for Expansion and Contraction; Tractive Stresses; Notes on Draw Bridges; Tanks; Greenhouses and Skylights; Gears; Inspection and Tests of Steel Work; Some Illustrations of Design in Various Classes of Structures; General Engineering Data; Specifications for Structural Steel Work; Definitions; Index.

THE SCIENCE OF BURNING LIQUID FUEL:

A Practical Book for Practical Men. By William Newton Best. Cloth, $9\frac{1}{4}$ x $6\frac{1}{4}$ in., illus., 159 pp. No place, The Author, 1913. $2.00.

In order to obtain the highest possible efficiency and the strictest economy from any installation for burning liquid fuel, the oil system, it is stated, must be installed and operated on sicentific principles. The author states that for the last twenty-five years he has made a study of such principles and has installed oil burners and applied designs for nearly every kind of furnace. In this book he has endeavored to supply his readers with information as to the exact service of boilers, furnaces, oils, etc., from a practical rather than a technical standpoint, by descriptions of the various installations required in an oil-burning system and by discussions of the results obtained with such system. It is further stated that the burners, furnaces and various installations described are fully protected by Letters Patent, and that all are in successful operation. The Contents are: Introduction; Liquid Fuel, Its Origin, Production and Analysis; Atomization; Oil Systems; Refractory Material; Locomotive Equipment; Stationary and Marine Boilers; Ovens; Furnaces; Index.

FREIGHT RATES: STUDIES IN RATE CONSTRUCTION.

By John P. Curran. Cloth, $9\frac{1}{4}$ x $6\frac{1}{4}$ in., 5 + 367 pp. Chicago, Railway Text Book Publishing Company, 1913. $5.00. (Donated by the Author.)

It is stated that the aim of the author has been to give, in a clear, concise manner, the bases or structures of freight rates which, he states, are based generally on scientific principles, and, for purposes of instruction only, to illus-

trate such principles. He prefaces his illustrations with a short history of transportation and freight rates. He also gives Sections 1 to 6 of the "Act to Regulate Commerce" passed by Congress in 1887, including the new matter substituted by the Act of June 18th, 1910. This is followed by the examples which include lists of groupings of stations in the various territories and the rates governed by the various Associations, examples of percentage bases, of the "group relation theory" and the basing point system, lake and rail rates, etc., etc.

THE GYROSCOPE.

By F. J. B. Cordeiro. Cloth, 8¼ x 5½ in., illus., 7 + 105 pp. New York, Spon & Chamberlain; London, E. & F. N. Spon, Limited, 1913. $1.50.

The development of the theory of gyroscopics is said to date from the time of Newton; its practical applications, however, are of modern date. In this book, the author offers, it is stated, a monograph on the subject, which may be easily understood by any one possessing an elementary knowledge of mechanics and the calculus. He has divided his subject-matter into two parts, namely, the development of the theory from the fundamental gyroscopic principle, and a discussion of its modern applications, such as the Griffin grinding mill, the Howell and Obry devices for keeping a torpedo in a straight course; the Schlick stabilisator for steadying the motion of ships, the Brennan gyro-monorail, the gyro-compass, etc., etc.

SAFETY:

Methods for Preventing Occupational and Other Accidents and Diseases. By William H. Tolman and Leonard B. Kendall. Cloth, 9 x 6 in., illus., 12 + 422 pp. New York and London, Harper & Brothers, 1913. $3.00.

It is believed, as stated in the Introduction, that men of affairs, business managers, officers, upper employees, students entering on industrial careers, and that portion of the public which is interested in the industrial and social issues of the day, will find that this book, which is said to be the first and only comprehensive work on the subject that has been issued in the English language, is of distinct value. It is a handbook of information for everyone interested in industrial conditions, and shows by typical examples from many sources, such as the prevention work and welfare bureaus of the Pennsylvania Railroad Company, the Midvale Steel Works, the United States Steel Corporation, etc., and various English and German plants, how to surround workers with adequate safeguards to protect them at work, and how to promote the essentials of shop hygiene; in fact, it is said to illustrate the underlying principles of the world movement for safety and industrial hygiene and welfare. The Contents are: Introduction; Part I, General Conditions: The Philosophy of Safety; Neglected Factors; The Working-Place. Part II, Danger Zones: Yards, Walks, Railings and Hoists; Cutting and Grinding Tools; Illumination; Fire; Transportation; Safety Committees; Iron and Steel; Mines and Mining; Electricity; General Aids to Safety; Organized Efforts by Employers. Part III, Industrial Hygiene: Committees on Sanitation; Industrial Poisons; Chemical Industries; Shop Sanitation. Part IV, Social Welfare: Industrial Education; Meeting the Public; Training Future Workers; Something More Than Wages; After Hours; The American Museum of Safety; Index.

ABHANDLUNGEN AUS DEM GEBIETE DER TECHNISCHEN MECHANIK.

Von Otto Mohr. Zweite Neubearbeitete und Erweiterte Auflage. Paper, 9½ x 6¾ in., illus., 12 + 567 pp. Berlin, Wilhelm Ernst & Sohn, 1914. 18 marks.

This book is a compilation, it is stated, of articles on applied mechanics which have appeared in various technical periodicals. The subject-matter embraces, it is said, the main points of elementary mechanics, the primary mathematics, and the elements of differential and integral calculus, and is intended for the use of students in building and mechanics. The text is fully illustrated, and, at the end of each chapter, a short bibliography of the subject discussed in that chapter, is given. Numerous other references to related subjects are also included. In this, the second edition, the text, the preface states, has been revised and numerous additions have been made, including two new chapters, one relating to stresses in dams and

the other to the theory of the simple girder. Chapter II contains new rules, by means of which, the author states, the treatment of the principles of graphic statics has been greatly simplified. In Chapter V, in which the test data relating to the strength of materials as given in the first edition are stated to have been criticized, more complete data are given to prove the author's hypothesis. In Chapter VI, relating to the study of earth pressures, it is stated that Coulomb's theory is shown to be untenable, and that the disputed points relating to earth pressures cannot be decided by tests. The Chapter headings are: Das Gleichgewicht und die unendlich kleinen Bewegungen eines starren Körpers; Die Grundzüge der graphischen Statik; Die Geometrie der Massen; Die Bewegung der ebenen Getriebe; Welche Umstände bedingen die Elastizitätsgrenzen und den Bruch eines Materials? Die Lehre vom Erddruck; Die Spannungen im prismatischen Balken; Die Spannungszustand einer Staumauer; Der kontinuierliche Balken; Die elastische Linie; Der vollwandige Bogenträger mit Kampfergelenken; Das ebene Fachwerk; Allgemeine Theorie der ebenen Träger; Das Raumfachwerk.

THE PANAMA GATEWAY.

By Joseph Bucklin Bishop. Cloth, 9 x 6 in., illus., 16 + 459 pp. New York, Charles Scribner's Sons, 1913. $2.50.

The author, as Secretary of the Isthmian Canal Commission, has had exceptional opportunities to study, in its various aspects, the work of constructing the Panama Canal, and in this book he gives a complete history of the Canal from its inception. He has divided the subject-matter into five parts: In Part I, Historical, 1502-1879, he relates the history of the Isthmus and of the transit routes across it from the time of Columbus to the period of the French Company's failure. In Part II, The French Effort and Failure, 1879-1902, he tells the story of the efforts and failures of the several French companies to construct a canal across the Isthmus. Part III, American Purchase and Control, 1902-1904, contains the history of the American occupation of the Canal Zone, and in Part IV, Period of Construction, 1904-1915, detailed descriptions of the work of organizing the Commissions and of constructing the Canal are given. Part V, The Completed Canal, describes the Canal as completed and ready for commerce. The Appendixes are: A, Canal Commissions; B, Canal Appropriations and Expenditures; C, An Act to Provide for the Opening, Maintenance, etc., of the Canal Zone; D, Equipment at Period of Greatest Activity; and E, Distances in Nautical Miles. There is also an Index of seven pages.

PRESS REFERENCE LIBRARY, VOL. I:

Notables of the West: Being the Portraits and Biographies of the Progressive Men of the West Who Have Helped in the Development and History Making of This Wonderful Country. Western Edition. Morocco, 11 x 8½ in., illus., 917 pp. New York, Chicago, San Francisco, etc., International News Service, 1913. $12.50. (Donated by the *Los Angeles Examiner.*)

As stated in the secondary title, this book, which is intended primarily as a reference work for the newspaper editor, writer and artist, contains portraits and short but complete biographies of about 1 200 men of note and achievement in the various professions and in business, in the West and Southwest. This volume is the first, it is said, of a work which eventually will cover most of the United States, other volumes of which are to follow at intervals. There is an alphabetical index of the names of the men included at the end of the book.

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DEATHS

MERRICK, HORACE GUY. Elected Associate Member, May 7th, 1913; died October 30th, 1913.

PONTZEN, ERNEST. Elected Corresponding Member, January 5th, 1876; died October 13th, 1913.

ZOLLINGER, LUTHER REESE. Elected Member, March 6th, 1901; died October 21st, 1913.

Total Membership of the Society, November 6th, 1913, 7 219.

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(October 2d to November 3d, 1913)

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(3) *Journal,* Franklin Inst., Philadelphia, Pa., 50c.
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(9) *Engineering Magazine,* New York City, 25c.
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(39) *Technisches Gemeindeblatt,* Berlin, Germany, 0, 70m.
(40) *Zentralblatt der Bauverwaltung,* Berlin, Germany, 60 pfg.
(41) *Elektrotechnische Zeitschrift,* Berlin, Germany.
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Bridges.

Specifications for Metal Railroad Bridges Movable in a Vertical Plane.* B. R. Leffler, M. Am. Soc. C. E. (54) Vol. 76.
Kinetic Effects of Crowds.* C. J. Tilden, Assoc. M. Am. Soc. C. E. (54) Vol. 76.
Maximum Stresses in Bascule Trusses.* W. Watters Pagon, Assoc. M. Am. Soc. C. E. (54) Vol. 76.
Notes on Bridgework.* S. Vilar y Boy, Assoc. M. Am. Soc. C. E. (54) Vol. 76.
The Sewickley Cantilever Bridge Over the Ohio River.* A. W. Buel, M. Am. Soc. C. E. (54) Vol. 76.
Construction Problems, Dumbarton Bridge, Central California Railway.* E. J. Schneider, M. Am. Soc. C. E. (54) Vol. 76.
A Shortened Method in Arch Computation.* H. A. Sewell. (54) Vol. 76.
The Construction of the Masonry for the New Quebec Bridge.* (12) Sept. 26.
Illinois River Bridge, St. L., P. & N. W. Ry. (87) Oct.
Concrete Railroad Bridges of Three Different Types.* A. M. Wolf (87) Oct.

*Illustrated.

Bridges—(Continued).

The Carondelet Park Bridge, St. Louis, Mo.* Charles W. Martin. (13) Oct. 2.
Kaministiquia River Bridge, Fort William.* (96) Oct. 2.
Double Deck Bascule Bridge.* (15) Oct. 3.
Bridges of the Connecticut Company.* (17) Oct. 4.
The Broadway Bridge, over Willamette River, Portland, Ore., with Rall Bascule Span.* W. P. Hardesty. (13) Oct. 9.
Bridges and Culverts for Country Roads. A. R. Hirst. (Paper read before the Am. Road Congress.) (13) Oct. 9; (14) Oct. 4; (96) Oct. 9; (86) Oct. 15.
Designing Concrete Spans for a Railroad Bridge. (14) Oct. 11.
Artistic Masks for Ugly Bridges.* (14) Oct. 11.
Direct-Lift Bridges.* (14) Oct. 11.
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Renewing Two Double Track Swing Spans. (15) Oct. 17.
Some Points Relative to the Design and Shipment of Plate Girders.* (86) Oct. 22.
A Description of the Principal Bridge Dams in the United States and in Foreign Countries. H. G. Tyrrell. (86) Oct. 22.
Specifications for Concrete Masonry in Highway Bridges. (96) Oct. 23.
The Design of Concrete Abutments without Wing Walls for Deck Girders.* C. M. Luther. (13) Oct. 23.
Equivalent Uniform Loads on Bridges for Different Types of Engine.* (13) Oct. 23.
New Bridge over the Rhine at Cologne.* Charles J. Kavanagh. (13) Oct. 30.
New Mississippi River Bridge at Memphis.* (15) Oct. 31.
Building a Ponton Bridge in Swift Water. T. H. Dillon. (100) Nov.
Deflection of Unstiffened Suspension Bridges.* G. B. Pillsbury, Assoc. M. Am. Soc. C. E. (100) Nov.
Le Pont de Schwarzenberg de l'Exposition de Leipzig.* (84) Sept.
Interessante, neuartige Brückenbauten in Eisenbeton.* Friedlaender. (51) Serial beginning Sup. No. 19.
Die neue Brückenbauwerkstatt für die Quebec-Brücke.* Müllenhoff. (69) Sept.
Zur Theorie der Drucklinien-Gewölbe.* Apád Gut. (53) Sept. 25.
Zwei Eisenbahnbrücken aus Eisenbeton.* Robert Berman. (78) Serial beginning Oct. 2.

Electrical.

An Electrical Measuring Machine.* P. E. Shaw. (75) Mar.
On the Goldschmidt Alternator.* Thomas R. Lyle. (Paper read before the British Assoc.) (73) Sept. 26.
Further Research of the Electric Arc as a Standard of Light.* J. F. Forrest. (Paper read before the British Assoc.) (73) Sept. 26.
Central Station Co-Operation in the Electric Vehicle Industry. Douglas Sutherland Martin. (9) Oct.
The Use of the Synchronous Commutator in Alternating Current Measurements.* Frederick Bedell. (3) Oct.
Notes on Oil Circuit Breakers for Large Powers and High Potentials.* K. C. Randall. (42) Oct.
Tungsten Lamps of High Efficiency.* Irving Langmuir and J. A. Orange. (42) Oct.
Relation of Plant Size to Power Cost.* P. M. Lincoln. (42) Oct.
Industrial Substations.* H. P. Liversidge. (42) Oct.
The Cost of Municipal Electric Lighting at Chicago. Ray Palmer. (Abstract of paper read before the City Club of Chicago.) (13) Oct. 2.
Waterwheel Generators.* (96) Oct. 2.
Some Experiments on Contacts Between Bad Conductors. W. H. Eccles. (Paper read before the British Assoc.) (73) Oct. 3.
The Electric Truck: English Experiments and American Practice.* (26) Oct. 3.
New Electric Carrier for Mail or Package Freight.* (14) Oct 4; (13) Oct. 2; (15) Oct. 3; (46) Oct. 4.
Power Generation and Transmission.* (17) Oct. 4.
Notes on the Present Status of Electric Furnaces. Wilfred Sykes. (Paper read before the Assoc. of Iron and Steel Elec. Engrs.) (62) Oct. 6; (20) Oct. 16.
Arc Lamps as Related to Shop Lighting.* Clarence E. Clewell. (72) Serial beginning Oct. 9.
Experiments on Corona Losses in Transmission Lines.* Weidig and Jaensch. (From *Elektrotechnische Zeitschrift.*) (73) Oct. 10.
Sine-Wave Transmission in the Submarine Telegraph Cable.* H. W. Malcolm. (73) Serial beginning Oct. 10.
Considerations in the Design of Head-Lamp Light Sources.* A. R. Dennington. (27) Oct. 11.
Measuring Currents in Underground Structures. Carl Hering. (17) Oct. 11.
Water Wheel Generators for the Newer Hydro-Electric Practice.* (62) Oct 13.
The Induction Motor.* F. A. Annett. (64) Serial beginning Oct. 14.
Report of the Committee on Power Generation. (Abstract of paper read before the Am. Elec. Ry. Eng. Assoc.) (17) Oct. 16.

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Report of the Committee on Electrolysis. (Abstract of paper read before the Am. Elec. Ry. Eng. Assoc.) **(17)** Oct. 16.
25 000 Kilowatt Parsons Turbo-Alternator.* **(11)** Oct. 17.
The 1912 Extension to Fisk Street Station. (Very Large Turbo-Generators.)* **(27)** Oct. 18.
Carbon and Impregnated Electrodes for Arc Lamps.* A. T. Baldwin. **(27)** Oct. 18.
A Canadian Electric Steel Furnace.* T. R. London. **(96)** Oct. 23.
Production of Poles and Cross-Ties, 1912, in Canada. **(96)** Oct. 23.
Wireless Telegraph Transmission Towers.* James Stedman. **(20)** Oct. 23.
Some Notes on Graphic Instruments (for Measurement of Electricity).* Kenelm Edgcumbe. (Paper read before the Arc Works Eng. Soc.) **(26)** Oct. 24.
The Electric Equipment of the New Building of the Institution of Civil Engineers.* **(73)** Oct. 24.
The Waterside Turbine Station at Louisville, Ky.* **(27)** Serial beginning Oct. 25.
Application of Electric Drive in Greenhouses.* **(27)** Oct. 25.
The Brush Discharge.* A. Vosmaer. **(105)** Nov.
How Inventors Use Ultra-Violet Rays.* **(46)** Nov. 1.
Hydroelectric Station on the Auglaize River.* **(27)** Nov. 1.
Nouveaux Dispositifs de Protection et de Renforcement des Poteaux de Lignes Electriques Aériennes.* P. Lecler. **(32)** Sept.
Der Elektromaschinenbau auf der Weltausstellung zu Gent.* Ernst Schulz. **(41)** Sept. 25.
Der neue Schnelltelegraph der Siemens & Halske A.-G.* A. Franke. **(41)** Serial beginning Sept. 25.
Die Kraftüberführungsprojekte Trollhättan-Kopenhagen (Costs). R. Johs. Jensen. **(41)** Sept. 25.
Turbodynamo für 20 000 Kva.* Friedr. Heinicke. **(41)** Oct. 2.
Das Kaiserliche Telegraphen-Versuchsamt.* K. Strecker. **(41)** Serial beginning Oct. 9.

Marine.

The Calculation of Stability in Non-Intact Conditions.* W. S. Abell. **(90)** Vol. 55, Pt. 1.
Recent Developments in Battleship Type.* Alan H. Burgoyne. **(90)** Vol. 55, Pt. 1.
The Influence of Air Pumps on the Military Efficiency of Turbine-Driven Warships.* D. B. Morison. **(90)** Vol. 55, Pt. 1.
Mechanical Gearing for the Propulsion of Ships.* Charles A. Parsons. **(90)** Vol. 55, Pt. 1.
Compressed Air for Working Auxiliaries in Ships Propelled by Internal Combustion Engines.* W. Reavell. **(90)** Vol. 55, Pt. 1.
On Large Deck-Houses.* J. Foster King. **(90)** Vol. 55, Pt. 1.
Methodical Experiments with Mercantile Ship Forms.* G. S. Baker. Vol. 55, Pt. 1.
Launching Declivities for Ships and Their Influence Upon Poppet and Way-End Pressures.* A. Hiley. **(90)** Vol. 55, Pt. 1.
Stresses in Stayed Cylindrical Shells.* C. E. Stromeyer. **(90)** Vol. 55, Pt. 1.
Propeller Experiments.* Ole G. Halvorsen. **(12)** Sept. 26.
Big Naval Guns. **(12)** Sept. 26.
Steel Screw Ferry-Boat *Edward T. Jeffrey*.* J. B. Shipley. **(95)** Oct.
Trial Runs of the Pacific Liner *Congress*. **(95)** Oct.
New Pacific Liner Built at Newport News.* **(95)** Oct.
Design of Propellers for Geared Turbines.* Peter Doig. **(95)** Oct.
New Shipbuilding Berth and 250-Ton Wharf Crane at the Blohm & Voss Shipyard.* **(95)** Oct.
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Western River Steamers, Engines and Boilers.* E. A. Burnside. **(95)** Nov.
Modern German Stern-Wheel Steamers.* E. Van der Werf. **(95)** Nov.
Shallow-Draft Producer Gas Motor Barges.* **(95)** Nov.
Armored River Monitors for Brazil.* F. C. Coleman. **(95)** Nov.
American Steamers on the Magdalena River.* **(95)** Nov.
Stern Recess Wheel Steamer *Osceola*.* **(95)** Nov.
Development of Producer Gas Motor Boats.* **(95)** Nov.
Ueber die Verwendung von Schleppkatzen und Spillen beim Verholen der Schiffe.* Möller. **(40)** Oct. 11.

Mechanical.

Beckton Works of the Gas Light and Coke Company. **(106)** Vol. 45, Pt. 1.
Notes on Modern Airship Construction.* A. Roenne. **(90)** Vol. 55, Pt. 1.

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The Longitudinal Stability of Skimmers and Hydro-Aeroplanes.* J. E. Steele. (90) Vol. 55, Pt. 1.
The Energy Systems Accompanying the Motion of Bodies Through Air and Water. J. B. Henderson. (90) Vol. 55, Pt. 1.
Belt Coal Conveyor at Middlesbrough.* (12) Sept. 26.
Diesel Engine Cylinder Dimensions.* (11) Sept. 26.
Steel Additions in the Iron Foundry Cupola.* (22) Sept. 26.
Some Aspects of Heat Flow.* E. F. Northrup. (Paper read before the Am. Electrochemical Soc.) (105) Oct.
Flow of Heat Through Furnace Walls, the Shape Factor. Irving Langmuir, E. Q. Adams and G. S. Meikle. (Paper read before the Am. Electrochemical Soc.) (105) Oct.
Securing Efficient Results in the Manufacture of Boilers.* Delbert E. Merrifield. (94) Oct.
Baker Ice Machine Company's Machine Shop, Omaha, Neb.* (108) Oct.
Elevators: Their Uses and Abuses. B. C. Van Emon. (Paper read before the Technical Soc. of the Pacific Coast.) (1) Oct.
The Manufacture and Uses of Portland Cement. L. M. Bailey. (Paper read before the Utah Soc. of Engrs.) (1) Oct.
Electric Cable Drills in a Cement Quarry. F. L. Jorgensen. (67) Oct.
An Economical Plant for Sand and Gravel.* Robert M. Hale. (67) Oct.
Atlas Concrete Pipe Machine.* (67) Oct.
Steam Curing Concrete Products. (67) Oct.
Electric Drive in Machine Shops. Charles Fair. (42) Oct.
Crushing Plant of the Rhyolite Crushed Rock Company.* (67) Oct.
Care of Motor Driven Fire Apparatus.* J. M. Taylor. (60) Oct.
Accurate Records of Street Main and Service Work.* Daniel L. Hill. (Paper read before the Canadian Gas Assoc.) (83) Oct. 1.
Designing Various Types of Reamers.* L. L. Haas. (72) Oct. 2.
An Energy Chart for Gas.* T. B. Morley. (11) Oct. 3.
Burgess Aeroplanes for the United States Government.* (11) Oct. 3.
Explosion of a Diesel Engine Receiver at Bray.* G. S. Taylor. (Report to the Home Office.) (47) Serial beginning Oct. 3.
Gas Plant at the Accrington Electricity Works.* (12) Oct. 3.
100 Horse-Power Avro Seaplane.* (12) Oct. 3.
Contributions to the Technology of the Paper Industry.* Clayton Beadle and Henry P. Stevens. (19) Oct. 4.
How Trees are Converted into Paper.* Thomas J. Keenan. (46) Oct. 4.
Public Service Rate Making. Alex. C. Humphreys. (Paper read before the Pacific Coast Gas Assoc.) (24) Oct. 6.
The Venturi Steam Meter.* Charles G. Richardson. (64) Oct. 7.
Cooling Towers for the Power Plant.* Everard Brown. (64) Oct. 7.
The Dempster-Toogood System of Continuous Vertical Retort Carbonization.* (66) Oct. 7.
Low Temperature Carbonization in Vacuo, in its Relation to the Production of Smokeless Fuel, Oils, and Motor Spirit.* F. D. Marshall. (Paper read before the Manchester and District Junior Gas Assoc.) (66) Oct. 7.
The Underpinning of a Retort-Bench. F. L. MacLaren. (Paper read before the Scottish Junior Gas Assoc.) (66) Oct. 7.
Thermal Testing Plant at the Pennsylvania State College. J. A. Moyer. (Abstract of paper read before the Inter. Congress of Refrigeration.) (13) Oct. 9.
The Story of Some Difficult Steel Castings, the Foundry, Machining, Testing and Transportation Problems of a Shaft Cover for New York's Catskill Aqueduct.* E. C. Jensen. (20) Oct. 9.
Casting Parts of a 6 000-H. P. Gas Engine.* (20) Oct. 9.
A Practical Chart for Determining the Horsepower of Spur Gears.* Frederic W. James. (13) Oct. 9.
The Dust-Precipitating Plant of the Riverside Portland Cement Co., Crestmore, Cal. (13) Oct. 9.
Empirical Design of Gas Engines.* G. W. Lewis and A. G. Kessler. (72) Oct. 9.
Development and Use of Chip Briquettes.* Hubert Hermanns. (72) Oct 9.
A New Strain-Gage for Live-Load Stresses.* (13) Oct. 9.
The Ljungström Radial-Flow Steam Turbine.* (26) Oct. 10.
A Contribution to the History of the Direct Recovery Process.* Otto Ohnesorge. (22) Oct. 10.
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The Biggest Flying Machine in the World, the Remarkable Biplane of Sikorsky.* (46) Oct. 11.
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The Gas Industry in Its Relation to Smoke Abatement. Vivian B. Lewes. (Paper read before the Conference on Coal Smoke Abatement.) (66) Oct. 14.
Notes on Gas Manufacture, the Koppers Chamber Ovens at Birmingham.* W. H. Johns. (Paper read before the Midland Junior Gas Assoc.) (66) Oct. 14.
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Carbonization in Bulk for Gas Production.* G. Stanley Cooper, M. Inst. M. E. (83) Oct. 15.
Construction of the Midway Gas Line.* W. E. Barrett. (From the *Journal of Electricity.*) (83) Oct. 15.
California Oil Gas Developments.* L. B. Jones. (83) Oct. 15.
The Astoria Tunnel under the East River, New York City (Consolidated Gas Co.).* Harold Carpenter. (13) Oct. 16.
Bucket Elevators. Reginald Trautschold. (96) Oct. 16.
The Electric Drive for Rolling Mills. Brent Wiley. (20) Oct. 16.
The Steam Friction of Turbine Wheels.* William Kerr. (Paper read before the Scientific Soc. of the Glasgow Royal Technical College.) (47) Serial beginning Oct. 17.
Southwestern Portland Cement Works.* Charles A. Smith. (16) Oct. 18.
Wet Bucket Elevator Design.* Arthur O. Gates. (16) Oct. 18.
Coal-Handling Plants for Panama. (From *Canal Record.*) (14) Oct. 18.
A Producer for Gasifying Gas Coke.* (24) Oct. 20.
Lentz Engines in Baltimore Office Building.* Warren O. Rogers. (64) Oct. 21.
Conservation of Coal and Liquid Fuel. (A Résumé of Papers read before the British Assoc. for the Advancement of Science.) (64) Oct. 21.
Making of Gray Iron Motor Car Castings.* H. B. Swan. (Paper read before the Am. Foundrymen's Assoc.) (20) Oct. 23.
The Essentials of Cam Design.* C. W. Sproull. (72) Serial beginning Oct. 23.
American Magnetic Speedometer Work.* Ethan Viall. (72) Oct. 23.
Kinetic Air-Ejector for the Commonwealth Edison Company, Chicago.* (11) Oct. 24.
The Polar-Diesel Engine.* (12) Oct. 24.
Catastrophic Instability in Aeroplanes.* F. W. Lancaster. (11) Oct. 24.
Thornycroft Water-Tube Boiler for Oil Fuel.* (11) Oct. 24.
A Coal-Handling Plant at Crewe.* (57) Oct. 24.
By-Product Coking and Benjol Recovery.* G. S. Cooper and Franz Puning. (Papers read before the Junior Institution of Engrs.) (22) Oct. 24.
Fuel Possibilities in Steel Making. William Whigham. (Abstract of paper read before the Am. Iron and Steel Inst.) (62) Oct. 27.
Use and Development of Refractories in the Iron and Steel Industry. Harry W. Croft. (Abstract of paper read before the Am. Iron and Steel Inst.) (62) Oct. 27.
Progress in Gas Engineering. Walter R. Addicks. (Paper read before the Am. Gas Inst.) (24) Oct. 27; (83) Nov. 1.
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Comparative Installation and Operating Costs of a Combined Ice-Manufacturing and Coal-Storage Plant. R. H. Tait and L. C. Nordmeyer. (Paper read before the Third Inter. Congress of Refrigeration.) (64) Oct. 28.
The Manufacture of Armor Plate.* D. K. Bullens. (20) Oct. 30.
A Modern Cement and Hydrated Lime Plant.* Richard K. Meade. (13) Oct. 30.
Progress in Steel Mill Roll Design.* Thomas H. Mathias. (Paper read before the Am. Iron and Steel Inst.) (20) Serial beginning Oct. 30.
A Forty-Foot Boring and Turning Mill.* E. A. Snverkrop. (24) Oct. 30.
Making Engines for Caterpillar Tractors.* F. A. Stanley. (24) Oct. 30.
Notes on the Standard Apparatus and Method for Measuring the Amount and Character of Atmospheric Pollutions.* John B. C. Kershaw. (105) Nov.
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Neuzeitliche Kabelkrane und ihre Anwendung auf das Bauwesen. M. Buhle. (51) Serial beginning Oct. 1.

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Gelöstes Azetylen oder Oelgas? (Wagen-Lampe.)* V. Schindler. (102) Oct. 1.
Ueber die Verwendung von Stahlkokillen.* Fritz Amende. (50) Oct. 2.
Ueber Abdampf-und Zweidruckturbinen.* K. Röder. (50) Oct. 2.
Statische Berechnung der Eisenkonstruktionen für eine Koksausdruckmaschinenbahn.* P. Hechtenberg. (78) Oct. 2.
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Zur Frage des Stickstoffs im Eisen.* W. Herwig. (50) Oct. 16.
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Metallurgical.

Developments in Lining Blastfurnaces.* C. A. Tupper. (From the *Iron Trade Review.*) (47) Sept. 26.
Desulphurizing Silver Ores at Cobalt.* James J. Denny. (103) Sept. 27.
Winona Stamp-Mill.* R. B. Seeber. (Abstract of paper read before the Lake Superior Min. Inst.) (105) Oct.
Mill Physiology. Stephen L. Goodale. (105) Oct.
Possible Applications of the Electric Furnace to Western Metallurgy. Dorsey A. Lyon and Robert M. Keeney. (Paper read before the Am. Electrochemical Soc.) (105) Oct.
The Art of Electric Zinc Smelting. Woolsey McA. Johnson. (Paper read before the Am. Electrochemical Soc.) (105) Oct.
The Electric Zinc Furnace. Peter E. Peterson. (Paper read before the Am. Electrochemical Soc.) (105) Oct.
The New Blast Furnace at Port Colborne, Ont.* (20) Oct. 2.
The Induction Furnace for Crucible Steel-Making. John Härdén. (22) Oct. 3; (105) Oct.
The Electric Furnace for Heat Treatment of Steel.* Robert Bain. (62) Oct. 6.
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Requirements of Small Cyanide Mills.* Algernon Del Mar. (16) Oct. 25.
Latest Blast Furnace at Youngstown, Ohio.* (20) Oct. 30.
The Manufacture of Armor Plate.* D. K. Bullens. (20) Oct. 30.
Condensation of Zinc Gas to Liquid, in the Presence of Inert Gas.* F. L. Clerc. (105) Nov.
Grinding Ores for Cyanidation. Herbert A. Megraw, (16) Serial beginning Nov. 1.

Military.

Canon de Campagne à Grands Champs de Tir du Colonel Deport.* D. Duaner. (33) Sept. 27.

Mining.

The Use of Cement for Excluding Water from Oil Sands in Drilling Wells. Paul M. Paine, Assoc. M. Am. Soc. C. E. (54) Vol. 76.
A Suggested Method of Preventing Rock Slides.* George S. Rice. (4) Sept.
Large Colliery Pumps.* (22) Sept. 26.
Machine Mining in the South Wales Steam Coals. G. D. Budge and W. E. Jayne. (Paper read before the South Wales Inst. of Engrs.) (57) Sept. 26.
The Cadder Pit Disaster. (Home Office Enquiry.) (57) Sept. 26; (22) Sept. 26.
The Nitrate Fields of Chile.* Walter S. Tower. (From the *Popular Science Monthly.*) (103) Sept. 27.
Gasoline Mine Locomotives. Carl Scholz. (45) Oct.
Rope Haulage at Vesta No. 4 Mine.* William Z. Price. (45) Oct.
Compressed-Air Mine Haulage.* William Z. Price. (45) Oct.
Slope Haulage at Sayreton, Alabama.* F. G. Morris. (45) Oct.
Cost of Mining as Related to Output.* R. C. Jones. (45) Oct.
Safety Gates for Shafts.* (45) Oct.
Gasoline Motors in Coal Mines.* A. J. King. (Paper read before the West Virginia Coal Min. Inst.) (45) Oct.
Natoma No. 7, a California All-Steel Dredge.* Lewis H. Eddy. (16) Oct. 4.
The Deep Borings in East Kent.* Malcolm Burr. (57) Oct. 10.
The Tayeh Iron Mine, China. Kimio Nishizawa. (29) Oct. 10.
Relining No. 2 Hamilton Shaft.* S. W. Tarr. (Abstract of paper read before the Lake Superior Min. Inst.) (16) Oct. 11.

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Availability of Motor Trucks for Mines. (16) Oct. 18.
Shaft Timbering in Butte Copper Mines.* Claude T. Rice. (82) Serial beginning Oct. 18.
Coal-Dust Explosion Test, Bureau of Mines.* Geo. S. Rice and L. M. Jones. (82) Oct. 18.
Explosion at Auckland Park Colliery.* R. A. S. Redmayne and A. D. Nicholson. (57) Oct. 24; (22) Oct. 24.
Winding Appliances, Winding Ropes and Capels: Past and Present.* A. S. Bratley. (Paper read before the National Assoc. of Colliery Mgrs.) (22) Oct. 24.
Blast-Hole Drilling in Open Pit Copper Mining.* (From *Colorado School of Mines Magazine.*) (103) Oct. 25; (82) Oct. 25.
A 30-Ton Electric Mining Locomotive.* (13) Oct. 30.
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Die Eisenbetonarbeiten beim Neubau der Steinkohlenseparation für den Nikolausschacht der Graf-Franz Grube in Ruda O.-S.* Egil Magelssen. (78) Oct. 2.

Miscellaneous.

Engineering Achievements and Activities of New York City.* Alfred D. Flinn, M. Am. Soc. C. E. (54) Vol. 76.
Bibliography on Valuation of Public Utilities. The Library Force, Am. Soc. C. E. (54) Vol. 76.
Some Tendencies and Problems of the Present Day and the Relation of the Engineer Thereto. George Fillmore Swain, President, Am. Soc. C. E. (54) Vol. 76.
The Status of the Lighting Art. Preston S. Millar. (Paper read before the Illuminating Eng. Soc.) (24) Oct. 13.
Progress in Illumination. (Report of Committee of the Illuminating Eng. Soc.) (83) Nov. 1.
Ueber graphische Integration von totalen Differentialgleichungen.* Ernst Meissner. (107) Serial beginning Oct. 11.

Municipal.

Street Sprinkling in St. Paul, Minn.* C. L. Annan, M. Am. Soc. C. E. (54) Vol. 76.
A Suggested Improvement in Building Water-Bound Macadam Roads. J. L. Meem, Assoc. M. Am. Soc. C. E. (54) Vol. 76.
Cities Beautiful by the Sea. John S. Brodie, M. Inst. C. E. (Paper read before the Institution of Mun. and County Engrs.) (104) Serial beginning Sept. 26.
Creosoted Wood Block Pavement in Longview, Texas. P. E. Green, Assoc. M. Am. Soc. C. E. (60) Oct.
Municipal Asphalt Plant of St. Louis, Mo.* (60) Oct.
California Highway Improvements. Roy M. Horton. (60) Oct.
A Report on the Use of Concrete as a Paving Material. P. E. Green. (86) Oct. 1.
Australasian Road Problems. J. M. Coane, M. Am. Soc. C. E. (Paper read before the Inter. Road Congress.) (104) Oct. 3.
Municipal Progress in Tiverton.* J. Siddalls. (104) Oct. 3.
Selection of Materials for Macadam Roads. Logan Waller Page. (Abstract of paper read before the Am. Road Congress.) (14) Oct. 4.
Typical California Concrete Road near Roseville.* (14) Oct. 4.
The Truth about Wayne Co. Roads.* Paul E. Green, M. Am. Soc. C. E. (76) Oct. 7.
Construction in France of Macadamized Roads Bound with Tarry, Bituminous or Asphaltic Materials. Wender, Le Gavrian, Mayer and Frontard. (Paper read before the Third Inter. Road Congress.) (86) Oct. 8.
Highway Accounting with Special Reference to Maintenance. Halbert P. Gillette. (Paper read before the Am. Road Congress.) (86) Oct. 8.
The Concrete Roads of Wayne County, Mich. Frank F. Rogers. (Paper read before the Am. Road Congress.) (13) Oct. 9.
Treatment of Worn Out and Raveled Macadam Road Surfaces. E. A. Stevens. (Paper read before the Am. Road Congress.) (13) Oct. 9; (96) Oct. 9.
Highways.* Charles Hamlet Cooper. (Paper read before the Soc. of Engrs.) (104) Oct. 10.
California's $18 000 000 State Highway System. Austin B. Fletcher. (Abstract of paper read before the Am. Road Congress.) (14) Oct. 14.
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Essential Features in Good Brick Road Construction. Jas. M. McCleary. (Paper read before the Am. Highway Assoc.) (96) Oct. 16.

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STORAGE TO BE PROVIDED IN IMPOUNDING RESERVOIRS FOR MUNICIPAL WATER SUPPLY.

By Allen Hazen, M. Am. Soc. C. E.

To be Presented December 17th, 1913.

There is undoubtedly a definite relation between the storage provided in an impounding reservoir on any stream and the quantity of water which can be supplied continuously by it. The relation, however, is a complex one, and our knowledge of its character is limited. The following study is made to see how far it may be possible to separate this complex relation into parts, some of them being of such a nature that they may be studied separately with definite results, and afterward to treat all the remaining variations on the basis of probabilities, using all data from a number of different streams; and to study them in comparison with the normal law of error.

Among the elements that can be studied separately are the following:

1. The size of the catchment area.

2. The mean annual run-off per square mile.

3. The portion of water area and the loss by evaporation from it. This relation is a complex one, and data for determining it are less adequate than could be desired. Nevertheless, some approximations can be reached.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

4. The natural storage in lakes, or in deposits of sand and gravel and other pervious materials. Only approximate results for natural storage can be reached, but as these are found to have a great influence on the required storage, especially at relatively low rates of draft, they must be considered.

5. Regularity in flow. Some streams have comparatively regular flows; in others the variation is much greater. This difference in regularity of flow can be taken into account by finding a coefficient determined from the record of each stream, and bringing this into the statement in such a way that variations from the normal are stated in terms of the "standard variation". In this way, records of streams having more regular flows and those having less regular flows may be compared with reference to other matters.

For the present, all remaining elements of variations of flow of every description will be thrown into one group and studied in connection with the normal law of error.

In general, it may be said that, as more information is secured as to any part of the whole problem, it tends to reduce unexplained variations, and to permit more accurate analysis of other parts. The whole study, therefore, becomes one of successive approximations. The results herein contained are to be taken as only one step in the development. It is to be expected that further study will show reasons for deviations, the causes of which are not now apparent, and will ultimately lead to more certain and accurate knowledge of the whole subject.

The methods developed in connection with the study of the normal law of error are well suited to an investigation of this kind. There is a presumption that they may be applied, growing out of experience with other kinds of data, but the presumption is not so strong that it is to be accepted without a careful study of the best flow data available, to see how close the agreement really is, and how far it may be depended on.

The first requisite to a successful study of probabilities is to have ample data. There are only a few cases where the records of stream flow cover a longer period than 25 years, and the longest record here used, that of the Croton River, covers only 45 years. No one of these records, taken by itself, is sufficient to serve as an adequate

basis for forming judgment of the probability of the recurrence of conditions which are only to be expected at intervals longer than are covered by these records.

In order to form a judgment of such conditions, we may either resort to the normal law of error, and assume that, if it applies reasonably to the data for short periods, it will also apply to longer ones; or we may combine the records of several streams, after eliminating all the elements that can be separated and eliminated, thus forming a single series containing the elements of unexplained variation reduced as nearly as possible to a common basis. In this way a series of results is built up which may be taken as representing the unexplained variations in the flow of a single stream for hundreds of years.

Such an artificial record is open to some objections. All the records of which it is composed were obtained in the same general period of time, and any changes in climatic conditions that might take place in a long term of years are not reflected by it. Nevertheless, such an artificial series seems to be the best means now available for finding approximately some of the relations between flow and storage.

Study Divided into Two Parts.—An impounding reservoir serves two purposes. These run into each other, more or less, and overlap, but they are nevertheless reasonably distinct, and can be best considered separately.

The first is to balance the fluctuations in flow during the seasons of one year. That is, to hold the flood flows of the winter and spring and make them available for maintaining the service during dry periods in the following summer and fall. This will be called the monthly storage.

The second is to hold the surplus water of wet years and make it available in the drier years that follow. This will be called the annual storage.

These matters will be taken up for discussion separately, and afterward the results will be combined in a single statement.

Approximate Methods Used.—In all hydraulic data the probable error of measurement is considerable. There is, therefore, no justification for the application of extreme refinements in methods of

calculation. With this in mind, slide-rule calculations have been used. In most cases, available records are given as monthly averages, and each month has been taken as one-twelfth of the year, regardless of the number of days it actually contained. In a few cases, daily or weekly records are available, and a brief investigation has been made as to the probable error involved by the use of monthly average figures instead of daily ones. Some changes of method have been made during the course of the work, and minor discrepancies resulting therefrom (too small to be significant) have not always been corrected. Where records from several streams are to be averaged, a weighted average is used in which each is given a value in proportion to the length of the records from which it is obtained.

Land Area Only as Basis.—In the case of many of the streams included in the following study, all or nearly all the catchment area is land; that is to say, it is not occupied by the water surface of reservoirs. In other cases, reservoirs or lakes have occupied a certain percentage of the area, and this percentage has gradually increased during the period covered by some of the records. The published records of flow are based on the whole area, including water surface. For the purpose of this study, the method of taking only land area as a starting point, as suggested by Mr. Stearns, has been followed. The published figures are revised by dividing the run-off per square mile from the total area, by one less the proportion of water area.

DATA USED.

The first step is to reduce existing data to a land-area basis, and make a tabular statement showing the average flow per square mile for each catchment area for each month for the whole period covered by the observations. The records of flow of the following streams have been used:

Sudbury River.—This is a part of the Boston water supply, with a catchment area of 75 sq. miles. The records cover the period from 1875 to 1896, inclusive, during which time the water area ranged from 2 to 4 per cent. The more recent records of the Sudbury River are not used, because, beginning with 1897, the water for Boston from the Wachusett catchment area was drawn through the Sudbury system, and the Sudbury figures are obtained as the difference between

the measurements of the water entering and leaving. As the quantities passing through are much larger than those originating in the area, the measurement is not believed to be sufficiently accurate to justify the use of the records since this condition has existed. The Sudbury catchment area is rolling, inhabited, and cultivated, and has much sand and gravel.

Wachusett Reservoir (South Fork of the Nashua River).—This is also a part of the Boston water supply. The records cover the period from 1897 to 1911, inclusive. The catchment area of 118 sq. miles is somewhat more hilly and higher in elevation than the Sudbury. It also contains a large quantity of sand and gravel. The water surface has ranged from 2 to 7 per cent.

Croton River.—This is a part of the New York water supply, with a catchment area of 339 sq. miles at the Old Croton Dam, increased in 1906 to 360 sq. miles at the New Croton Dam. The records cover the period from 1868 to 1912, inclusive, during which time the water area has ranged from 2 to 5 per cent. The catchment area is rolling, is cultivated to a considerable extent, and has a large quantity of sand and gravel.

Manhan River.—This has a small catchment area of 13 sq. miles, forming part of the water supply of Holyoke, Mass. The measurements were made by weirs, with unusual care, and cover the period from 1897 to 1910, inclusive. The area is rolling, and the quantity of sand and gravel is large.

Catskill Streams.—These include the Esopus, 378 sq. miles; Schoharie, 240 sq. miles; and Rondout Creek, 105 sq. miles. The gaugings were made by the City of New York, and cover a relatively short period. The catchment areas are steep and mountainous, and largely wooded. The soil is generally impervious, and there is little sand and gravel. The records are not of sufficient length to cover the driest periods, but they are useful as indicating the ordinary conditions of storage required in catchment areas differing radically in physical characteristics from those previously mentioned.

Pequannock River.—This furnishes the water supply for Newark, N. J. It has a catchment area of 62 sq. miles of hilly, almost mountainous country, cultivated to a moderate extent, but largely covered with second-growth forest. The record covers the period from

1892 to 1911, inclusive, and is made up of Venturi measurements of the water taken out of the catchment area for use, and weir measurements of the water washing over the intake dam. The water area is about 4 per cent.

Philadelphia Streams.—Three streams, Perkiomen Creek, 152 sq. miles; Neshaminy Creek, 139 sq. miles; and Tohickon Creek, 102 sq. miles, were proposed many years ago as sources of additional water supply for Philadelphia. They were not used as proposed, but careful gaugings, extending over a period of 25 years, are available. The country is hilly and partly cultivated.

Gunpowder River.—This furnishes the water supply for Baltimore, Md. The catchment area is 308 sq. miles of hilly, rolling country, under a good state of cultivation. The hills are high and steep, but there is a deep cover of fine-grained micaceous sandy material on a large part of the area, and this serves to store a large quantity of water, so that the ground-water flow of this stream is larger relatively than of any other stream considered. The records are made up of the quantity of water drawn for use by the City of Baltimore, and that flowing over the intake dam, calculated from the records of gauge heights covering the period from 1883 to 1911, inclusive. In considering these records, in their report on the water supply, Messrs. Freeman and Stearns reduced them slightly because they believed that the coefficient to be used in the weir formula, for the crest of the dam as it existed, was lower than had been assumed in making up the quantities used by the Water Department. In this calculation the records are used without correction.

Merrimac River.—The Merrimac River drains an area of 4 634 sq. miles. The record of the flow at the Lawrence Dam has been kept by the Essex Company. Lake Winnepesaukee and many smaller lakes, comprising 2.6% of the total catchment area, are included in this area, and storage in them, either natural or with the aid of the control works at the outlets of some of the lakes, is an element in maintaining the regularity of the flows. No correction for water area has been made in the Merrimac flows.

Hudson River.—A record of the flow has been kept at Mechanicsville, where the catchment area is 4 500 sq. miles. As with the Merrimac, there are numerous lakes on the catchment area, and natural

storage is an element in maintaining the flows. No correction has been applied for water area.

Colorado Streams.—The gaugings of three streams used by the Denver Union Water Company are available:

1. Bear Creek; record, 1900 to 1911, inclusive, and a catchment area of 172 sq. miles;

2. South Fork of the South Platte River; record, 1900 to 1911, inclusive, and a catchment area of 1 796 sq. miles;

3. South Platte River at Platte Canyon; record, 1903 to 1911, inclusive, and a catchment area of 2 688 sq. miles.

These streams were included as typical ones in a dry country where the variation in flow from year to year is much greater than in any of those previously mentioned. The seasonal fluctuation in flow also depends on different climatic conditions, especially on the accumulation of snow in the high mountains, and its melting in summer. These streams were included in the study in order to see how far the same methods of calculation would be applicable to them, and with the idea that they would be included in summaries with the eastern streams only if it became apparent that doing so would not modify materially the standards reached. Including these western streams has the important advantage that it tends to broaden the methods used for comparing data, so that they are applicable under a greater variety of conditions.

Not all the sources mentioned were used for all parts of the following study, but only such records as seemed most appropriate in relation to each point taken up in turn.

Additional Records.—It would be possible, by using the records of the United States Geological Survey, greatly to extend the investigation. In the first study it is thought best to use only a limited number of selected data. It is by no means an easy matter to gauge streams accurately, especially under winter conditions in northern climates, with large quantities of ice and anchor ice in the water. It is necessary, therefore, to use these records with caution, because such errors may exist in some of them. Long-term records are obviously more useful than those of short term, and the latter have been considered only in the case of a few streams representing types of catchment area not otherwise included.

Calculation of Storage.—Calculations were made for each year for each of the streams investigated in order to determine the storage required to maintain each of a number of assumed rates of draft. For most of the streams, for which the flows were given in gallons per square mile, these calculations were made for rates of draft of 100 000, 200 000, 400 000, 600 000, 800 000, and 1 000 000 gal. daily per sq. mile of land area, or for so many of them as required storage and could be supported. In the case of streams where the records were in cubic feet per second, rates of draft were taken giving about the same general range.

Basis of Stating Storage.—There are several ways in which the storage may be stated: In terms of the land area, in terms of the mean annual run-off, or in terms of the proposed maintainable draft.

When storage is based on the tributary area, it may be stated as inches of run-off or millions of gallons per square mile of tributary area. These and similar terms bear fixed relations to each other. Thus 1 in. of run-off is always equal to 17 400 000 gal. per sq. mile. When these units are used, it should be stated whether they relate to the whole area or to the land area only, as either form may be used. When the storage is based on the mean annual flow, the percentage of it required to fill the reservoir from bottom to top is usually given. When the storage is based on the maintainable yield, it is most conveniently stated in days' supply. Thus, if a given reservoir holds 100 000 000 gal., and is used for an output of 2 000 000 gal. per day, 50 days' storage is said to be provided. Each of these three ways of stating storage has advantages for certain purposes, and they are all used in this discussion.

Monthly Storage.

Each Year by Itself.—It is assumed, in the first part of this study, that the reservoir is full each year at the beginning of the summer dry period, and no account is taken of any deficiency that might exist from operations of previous years. The figures thus reached are referred to as those for "each year by itself" or as "monthly storage". A second set of figures is made in which the deficiency at the beginning of any year is carried forward. The figures thus reached are spoken of as "cumulative". The cumulative figures are comparable with those made by Messrs. Stearns, FitzGerald, and Freeman for a zero water area.

At the outset it was supposed that the cumulative figures would be the most important, and those representing each year by itself were carried as a convenient and perhaps useful check. It turned out, however, that the figures for each year by itself could be reduced to more definite and satisfactory order than was possible for the cumulative figures, and in the final study no use is made of the latter, except as a check on the results otherwise reached.

The monthly storage figures, representing the storage for each year by itself, are used as a convenient step in the process of development, and do not always represent the whole quantity of storage required, as they contain no allowance for the annual storage necessary to hold the excess water of wet years and make it available in dry ones.

The figures for monthly and annual flow for each of the streams, and the computed storage therefrom for several assumed rates of draft, are compiled in Table 1. As the original of this table is very long, and as all the figures used in the subsequent discussion are shown graphically in the diagrams which follow, the table is not presented in full, but only one part of it, containing the records of one stream, in order to show its form.

Plotting Results.—On Fig. 1 are plotted these results for the Wachusett Reservoir. The quantities of storage for each rate of draft are arranged in order of magnitude and plotted on lines equally spaced on the diagram. Lines connecting them approximate in shape to the letter "S", the middle part of the curve being moderately straight, and the curvature near the ends much sharper.

Smooth curves have been drawn to show the most probable curve in case the normal law of error applies to the data. The question as to whether it does apply will not be discussed at this time, but the lines drawn with its aid give a better idea of the normal shape of the curves than can be obtained from the few points that constitute this particular series. If the data were much more numerous, a fair approximation of positions near the ends, that is to say, of the probable storage required to maintain drafts in years so dry that they recur only once in 20 or 50 years, could be obtained.

With data no more numerous than those in the record shown by Fig. 1, the method is a clumsy one, and cannot be expected to yield close results. It may be pointed out, however, that the method

TABLE 1.—(IN PART.)—AVERAGE RUN-OFF, BY MONTHS, IN THOUSANDS OF GALLONS PER DAY PER SQUARE MILE OF NET LAND AREA, FOR WACHUSETT RESERVOIR.

Year.	Percentage of water area.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1897	2.2	815	954	2 822	1 669	1 189	1 208	1 474	916	389	248	1 312	2 326	1 281
1898	2.2	1 598	1 672	3 157	2 072	1 421	847	341	1 355	692	1 543	2 219	2 107	1 586
1899	2.2	2 139	1 115	2 838	3 452	882	574	362	242	256	251	440	367	1 075
1900	2.2	814	4 144	3 806	1 616	1 413	591	222	201	131	289	895	1 605	1 292
1901	2.2	531	364	2 779	5 098	2 790	1 007	488	524	327	662	529	3 307	1 541
1902	2.2	1 714	1 432	4 081	2 207	1 054	419	299	304	247	973	650	1 889	1 276
1903	2.4	1 296	2 185	3 507	2 293	583	2 183	639	486	384	705	649	976	1 316
1904	3.6	684	962	3 120	3 095	1 554	791	515	368	512	360	356	457	1 063
1905	4.1	1 320	472	3 132	1 686	464	565	381	335	1 280	383	461	1 061	965
1906	5.1	1 193	1 082	1 960	2 222	1 615	1 248	768	623	292	559	790	836	1 099
1907	6.0	1 551	736	1 805	1 528	1 027	822	356	93	861	1 470	2 702	2 086	1 255
1908	7.0	1 869	1 867	2 357	1 364	1 521	434	237	476	95	170	134	416	910
1909	7.0	637	2 748	2 289	2 604	1 303	680	251	208	224	97	391	578	987
1910	7.0	1 985	1 984	2 839	1 112	655	886	67	200	156	73	381	420	890
1911	7.0	832	672	1 440	1 498	496	377	61	202	195	773	1 113	1 147	733

COMPUTED STORAGE, IN MILLIONS OF GALLONS PER SQUARE MILE OF NET LAND AREA, FOR SEVERAL RATES OF DRAFT. EACH YEAR IS CONSIDERED BY ITSELF, EXCEPT THAT WHERE CUMULATIVE STORAGE IS GREATER, THE FIGURE FOR IT IS GIVEN IN PARENTHESES.

Year.	Computed Storage, in Millions of Gallons per Square Mile of Land Area, for Drafts as Marked.					
	100 000	200 000	400 000	600 000	800 000	1 000 000
1897........	0	0	5	17	29	44
1898........	0	0	2	8	14	25
1899........	0	0	15	52	95	147
1900........	0	2	23	48	78	127
1901........	0	0	2	14	45	75
1902........	0	0	11	35	59	95
1903........	0	0	0.5	10	35	77
1904........	0	0	3	31	68	118
1905........	0	0	3	20	53 (127)	95
1906........	0	0	3	11	30 (189)	65
1907........	0.2	3	11	23	35 (96)	57
1908........	0.2	6	27	68	116	165
1909........	0.1	3	25	57	97 (154)	140
1910........	1.0	9	34	70	112 (206)	173
1911........	1.2	4	23 (59)	51 (153)	82 (297)	119

which has been most commonly used for estimating storage has been that of considering only the highest term in the storage series, and that no consideration has usually been given to the other terms.

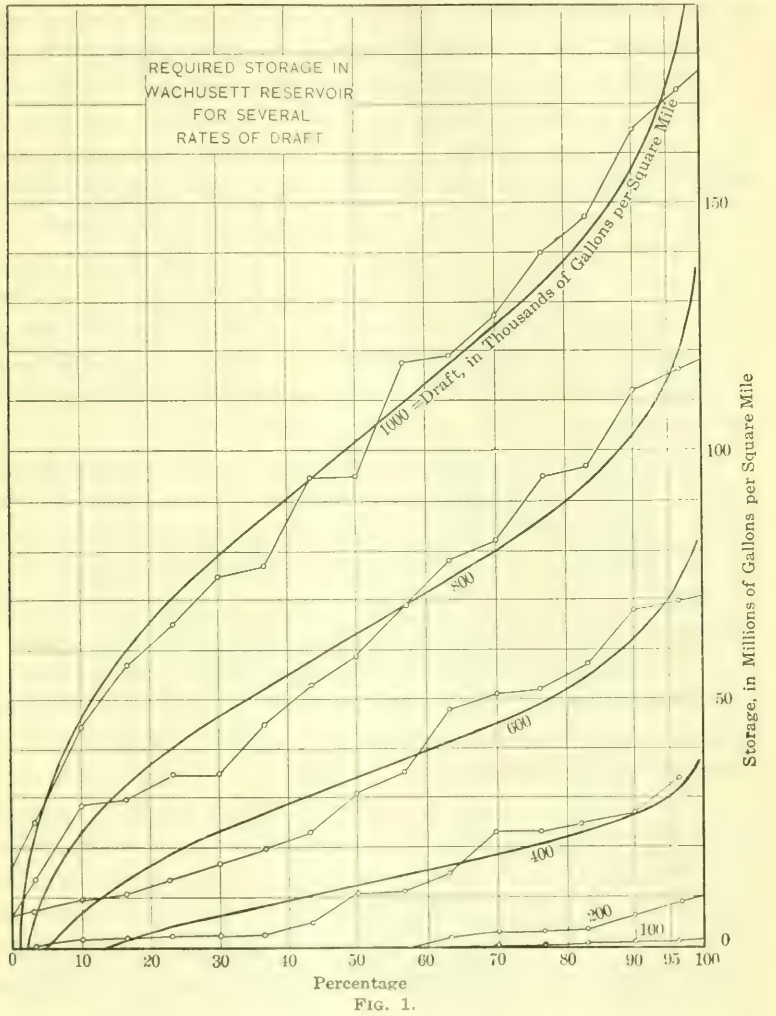


FIG. 1.

Under these conditions, the degree of dryness of the year that controls is a matter of chance. The longer the record period, the greater is the chance that it will include a very dry year. Plotting in even this crude way is an improvement, in that it gives some idea of the

range of results and the frequency of recurrence of extreme values.

Probability Paper.—The practical difficulty with the plotting on Fig. 1 is the great curvature of the lines showing the required storage. This difficulty is so great as to make the method impracticable in most cases; but it has been removed by using paper ruled with lines spaced in accordance with a probability curve, or, as it is otherwise called, the normal law of error. The spacing of the lines for this paper was computed from figures taken from probability curve tables, and arranged so that the line which represents the summation of the probability curve, when plotted on it, is straight. If the data for any series correspond strictly with the normal law of error, the points plotted on this paper will all be in a straight line. If the data approximate the normal law of error, the line through the points will approximate a straight line. Even though the deviation from the normal law of error is considerable, a line with only a moderate curvature may represent it fairly well.

In plotting observations on this paper, either of two methods may be used. First, all the results may be divided into classes between certain limits, and the corresponding limits in the other direction may be determined and plotted. This is the better method where the number of terms in the series is large. It cannot be well used with the relatively small number of terms ordinarily constituting a series of storage data. In the second method the whole space is divided into as many vertical strips as there are terms, and the figure for each term, arranged in its order of magnitude, is plotted at the percentage which corresponds to the middle of its strip. That is to say, if there are 50 terms in the series, each is taken to represent 2% of the whole space. The first term will be plotted at the middle of the first 2% strip; that is, on the 1% line; the second term will be plotted in the middle of the second strip, or on the 3% line, etc. The position for plotting results can be obtained with sufficient accuracy with a 10-in. slide-rule. The decimal position of the mth term in a series of n terms is found to be $P = \frac{2\,m - 1}{2\,n}$.

Storage Data on Probability Paper.—On Fig. 2 are plotted on probability paper the same data that were plotted to natural scale in Fig. 1. It is seen that the sharp curvature at the ends is entirely

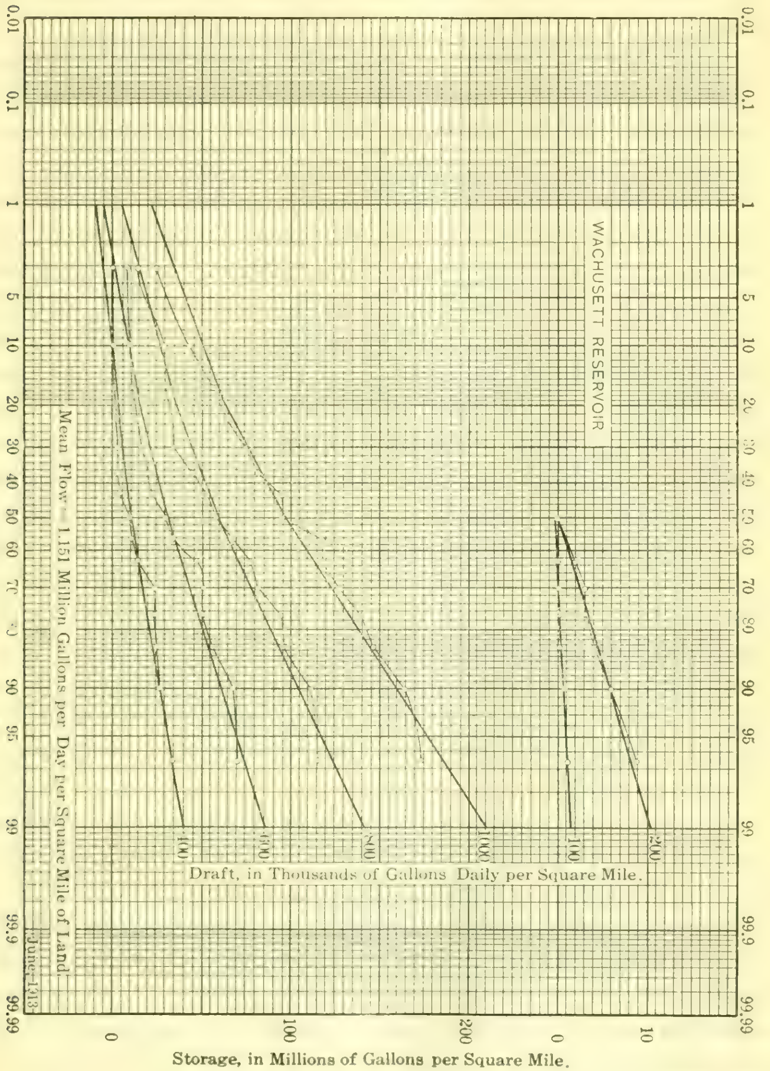

WACHUSETT RESERVOIR
Mean Flow = 1.151 Million Gallons per Day per Square Mile of Land.
Draft, in Thousands of Gallons Daily per Square Mile.
400
600
800
1000
100
200
0.01 0.1 1 5 10 20 30 40 50 60 70 80 90 95 99 99.9 99.99
0 100 200 0 10
Storage, in Millions of Gallons per Square Mile.
June 1913

FIG. 2.

eliminated. The lines representing the several series have only a moderate curvature, and this is much the same in the different cases. This method represents the data more satisfactorily than arithmetical plotting.

The diagrams, Figs. 3 to 21, inclusive, represent all the data from the other streams mentioned, arranged in the same way; and, as these diagrams are the most convenient means of showing these data, and are sufficiently accurate, the actual figures are not presented.

In the case of three of the streams, namely, the Croton and Sudbury Rivers and the Wachusett Reservoir, three plottings are made for each. The first represents the flow as it occurred, without correction for loss by evaporation from the water area. The second contains the storages required to balance the calculated flows for all land area. In making the correction, it has been assumed, first, that the actual flow was increased each month by the rainfall on the actual water area of the system as it existed at that time, and second, that the flow was decreased by the evaporation for that calendar month, as found by Mr. FitzGerald in his experiments at Chestnut Hill Reservoir.* The third diagram represents the required storage to balance the calculated flows from a land area of 1 sq. mile to which there is attached 0.1 sq. mile of water surface. The allowances for rainfall and evaporation have been made in the same way.

The data have been computed and arranged in this way with the idea of showing the effect of water area on stream flow, and on the required storage; and certain deductions will be made from them as the study proceeds.

In drawing the smooth curves on the several diagrams, a uniform procedure, to be described later, has been followed, giving a definite and nearly constant curvature, this being deduced from a study of all the series here presented. The same procedure has been followed in the few cases where the data for one series alone would indicate either more curvature or less than the line as drawn. For the streams where the records have been longest continued, the agreement of the lines with the actual records is satisfactory. For the shorter records the results are less regular, owing to the fact that they are not numerous enough to have filled in all the values that would be expected in a long-term series.

* *Transactions*, Am. Soc. C. E., Vol. XV, p. 581.

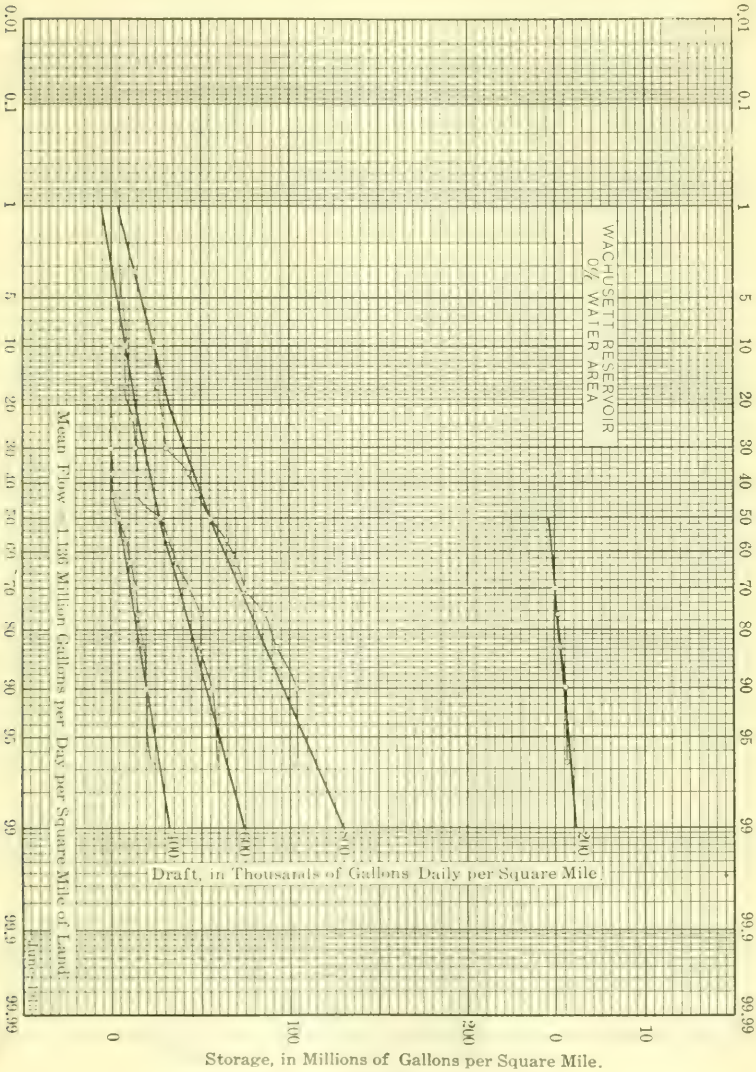

WACHUSETT RESERVOIR
0% WATER AREA
Mean Flow = 1.136 Million Gallons per Day per Square Mile of Land.
Draft, in Thousands of Gallons Daily per Square Mile
0.01
0.1
1
5
10
20
30
40
50
60
70
80
90
95
99
99.9
99.99
100
200
0
10
Storage, in Millions of Gallons per Square Mile.

FIG. 3.


WACHUSETT RESERVOIR
10% WATER AREA
Mean Flow = 1.170 Million Gallons per Day per Square Mile of Land.
Draft, in Thousands of Gallons Daily per Square Mile.
Storage, in Millions of Gallons per Square Mile.
June, 1913

Fig. 4.

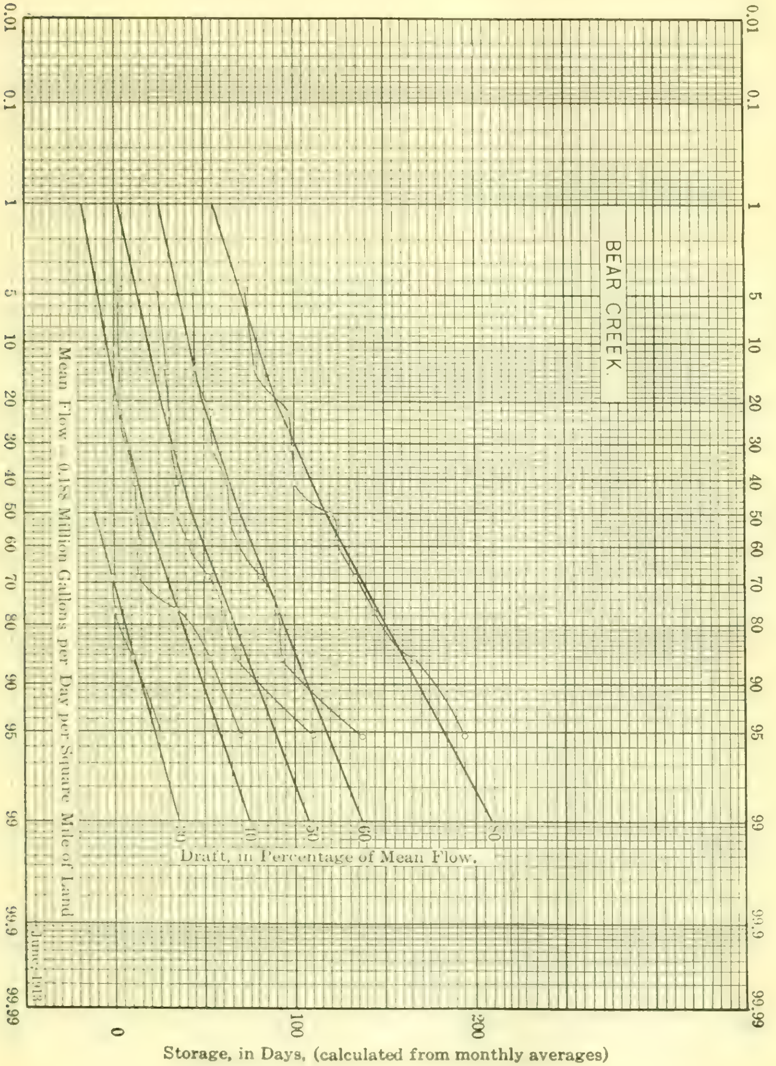

BEAR CREEK.
Mean Flow = 0.188 Million Gallons per Day per Square Mile of Land
Draft, in Percentage of Mean Flow.
20
40
50
60
80
June, 1913
0.01
0.1
1
5
10
20
30
40
50
60
70
80
90
95
99
99.9
99.99
0
100
200
Storage, in Days, (calculated from monthly averages)

FIG. 5.


CATSKILL STREAMS
Draft, in Thousands of Gallons Daily per Square Mile
Storage, in Millions of Gallons per Square Mile
June, 1913

FIG. 6.

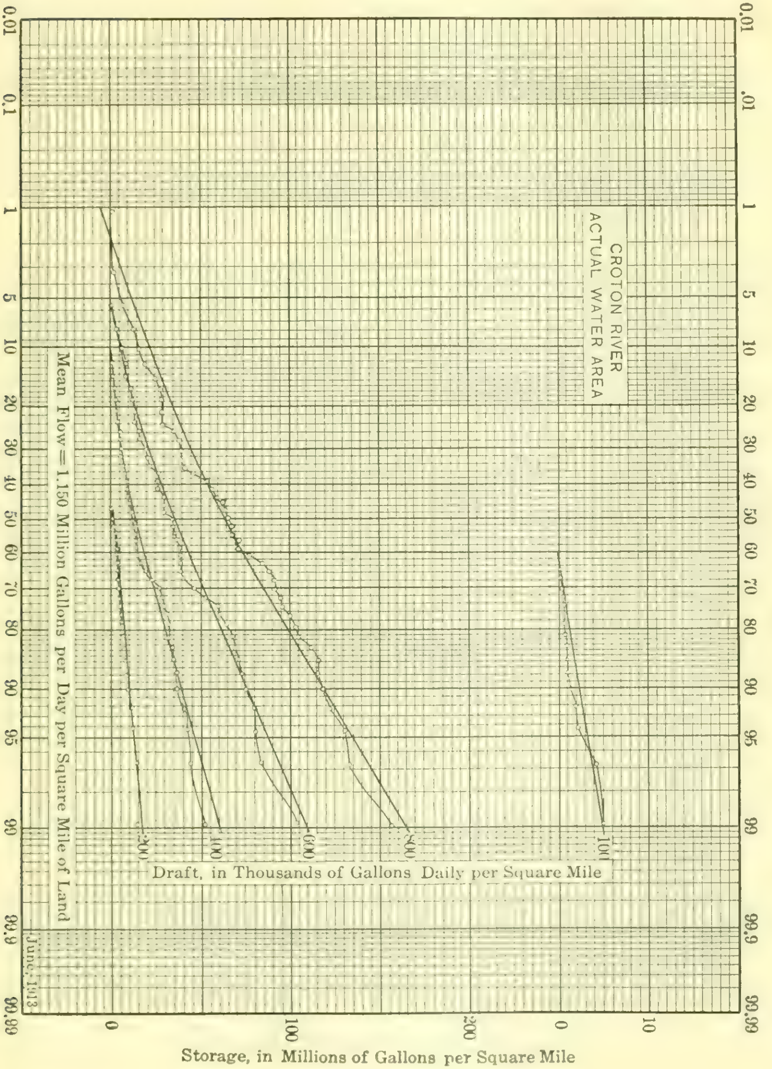

CROTON RIVER
ACTUAL WATER AREA
Mean Flow = 1.150 Million Gallons per Day per Square Mile of Land
Draft, in Thousands of Gallons Daily per Square Mile
200
400
600
800
100
Storage, in Millions of Gallons per Square Mile
0
100
200
0
10
0.01
0.1
1
5
10
20
30
40
50
60
70
80
90
95
99
99.9
99.99
June, 1913

Fig. 7.

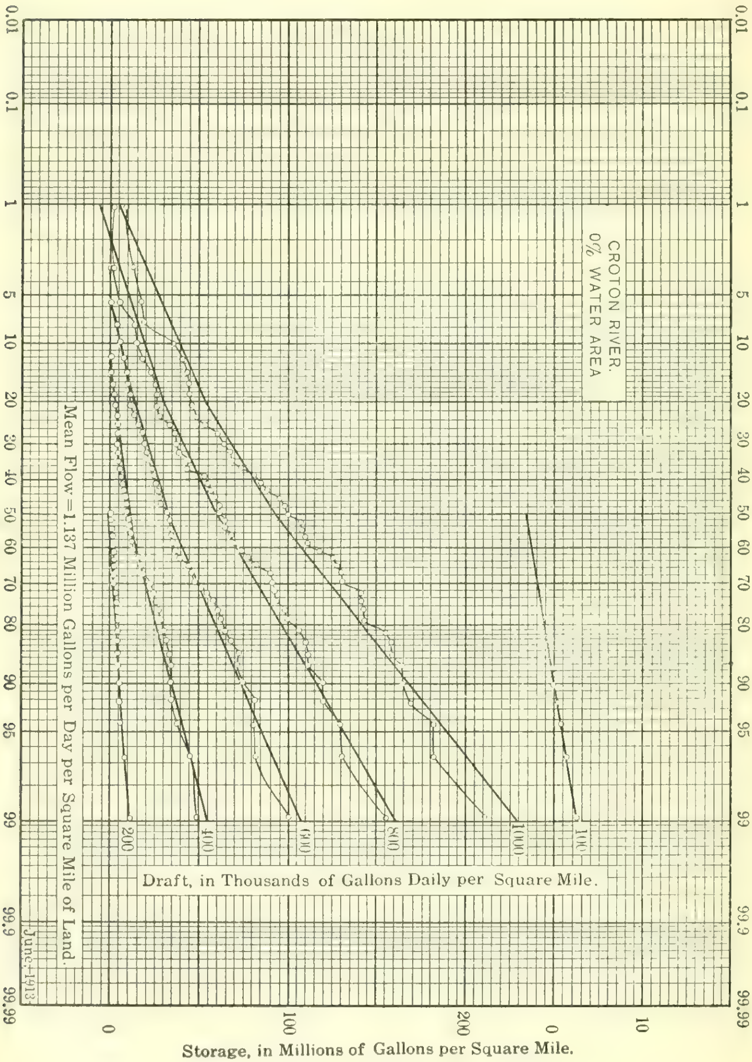

CROTON RIVER.
0% WATER AREA
Mean Flow = 1.137 Million Gallons per Day per Square Mile of Land.
Draft, in Thousands of Gallons Daily per Square Mile.
200
400
600
800
1000
100
June-1913
0.01
0.1
1
5
10
20
30
40
50
60
70
80
90
95
99
99.9
99.99
0
100
200
0
10
Storage, in Millions of Gallons per Square Mile.

FIG. 8.

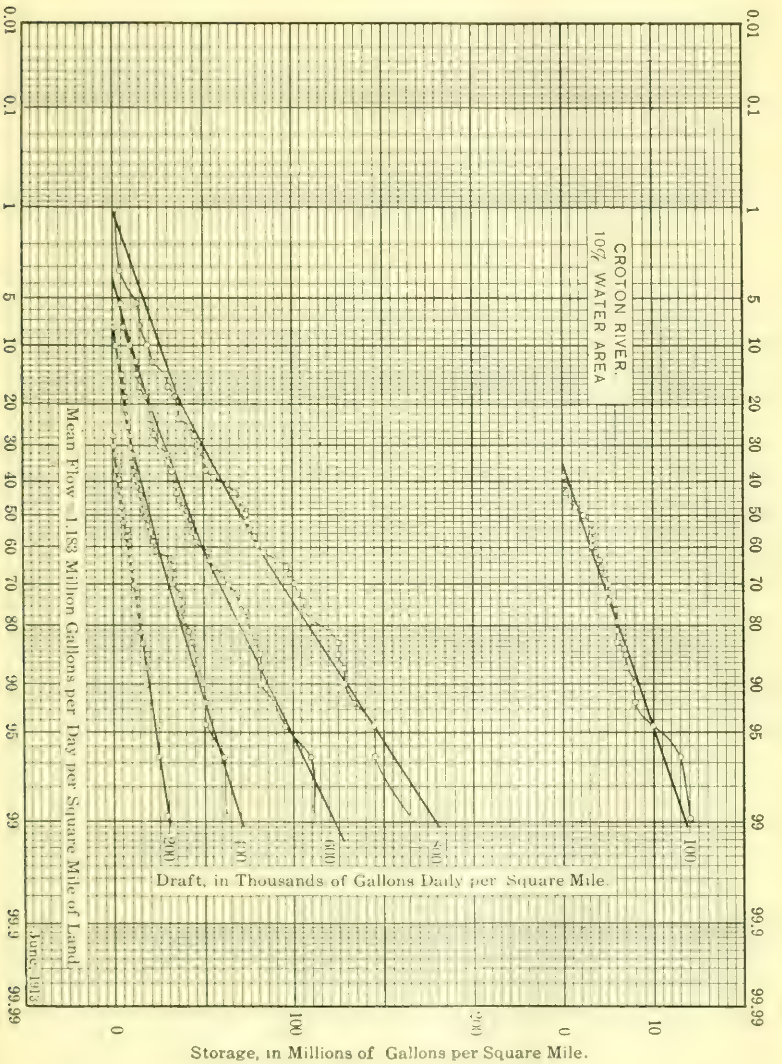

CROTON RIVER.
10% WATER AREA
Mean Flow 1.183 Million Gallons per Day per Square Mile of Land
Draft, in Thousands of Gallons Daily per Square Mile.
Storage, in Millions of Gallons per Square Mile.
June, 1913

Fig. 9

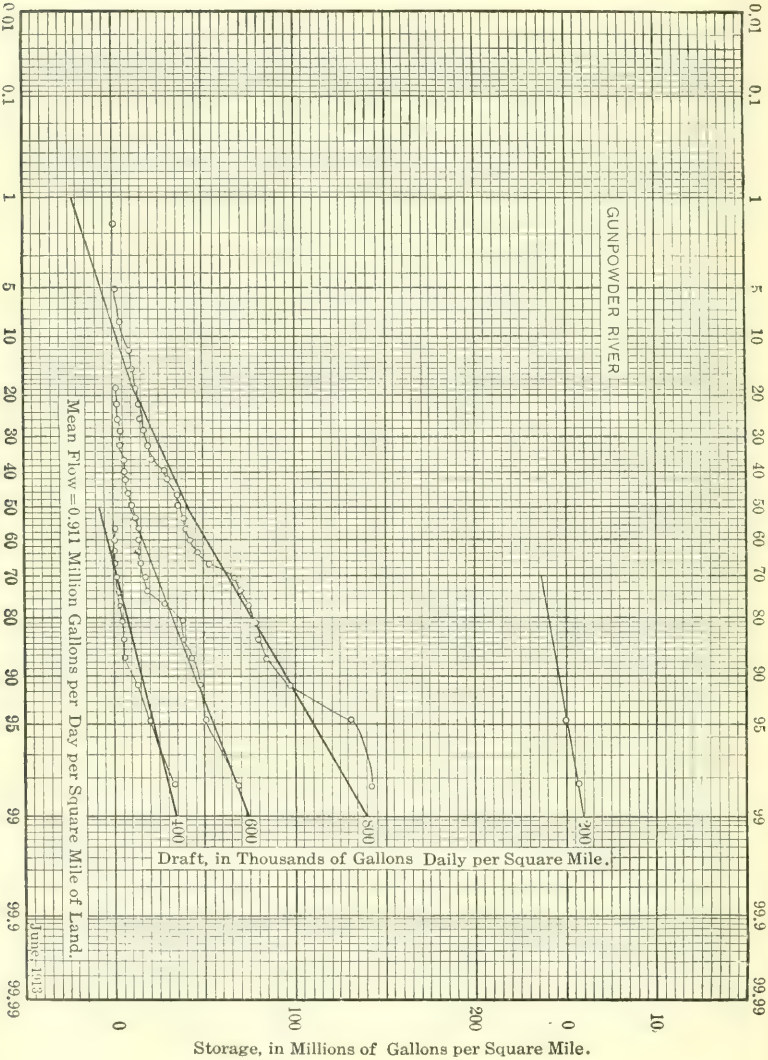

GUNPOWDER RIVER
Mean Flow = 0.911 Million Gallons per Day per Square Mile of Land.
Draft, in Thousands of Gallons Daily per Square Mile.
400
600
800
200
June, 1913
0.01
0.1
1
5
10
20
30
40
50
60
70
80
90
95
99
99.9
99.99
0
100
200
0
10
Storage, in Millions of Gallons per Square Mile.

FIG. 10.

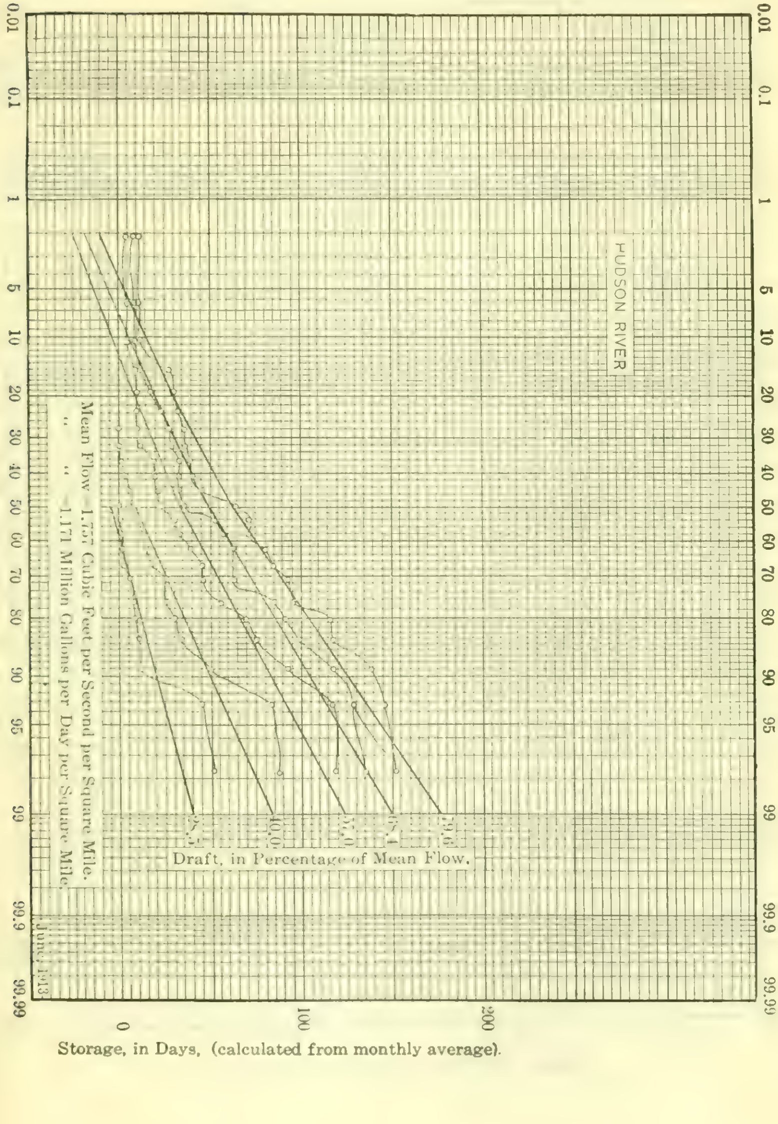

HUDSON RIVER
Mean Flow 1.757 Cubic Feet per Second per Square Mile.
" " 1.171 Million Gallons per Day per Square Mile.
Draft, in Percentage of Mean Flow.
40.0
June, 1913
Storage, in Days, (calculated from monthly average).

FIG. 11.

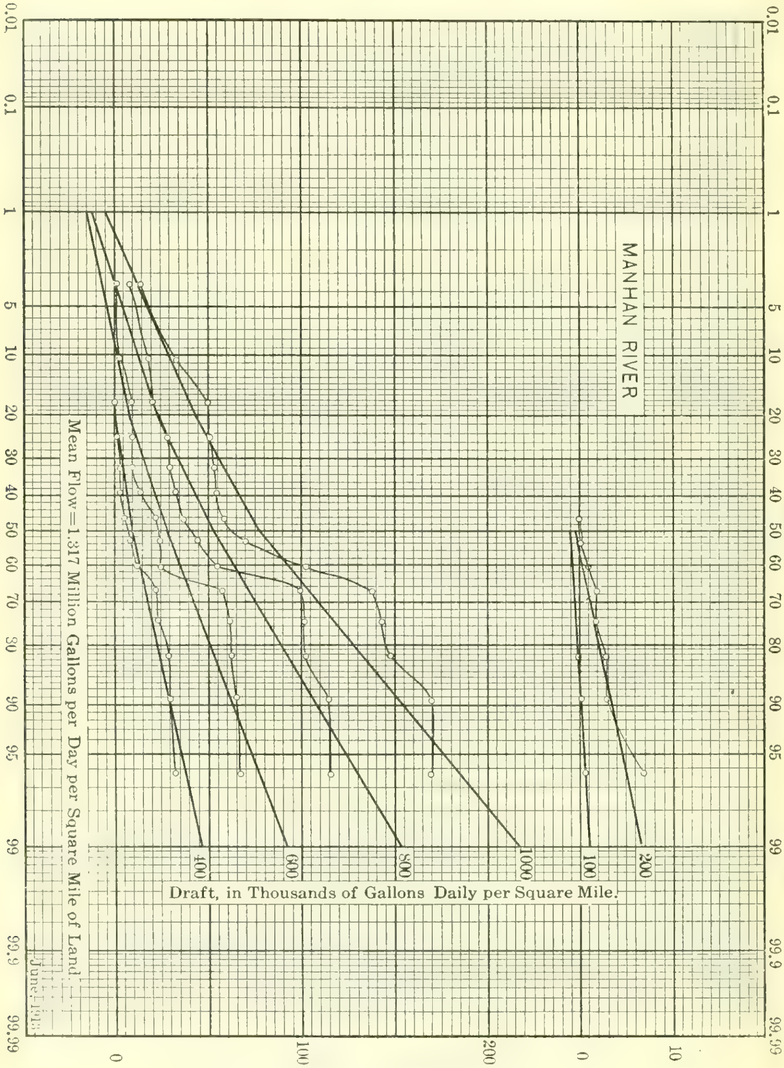

MANHAN RIVER
Mean Flow=1.317 Million Gallons per Day per Square Mile of Land.
Draft, in Thousands of Gallons Daily per Square Mile.
400
600
800
1000
100
200
Storage, in Millions of Gallons per Square Mile.
0
100
200
0
10
0.01
0.1
1
5
10
20
30
40
50
60
70
80
90
95
99
99.9
99.99

FIG. 12.

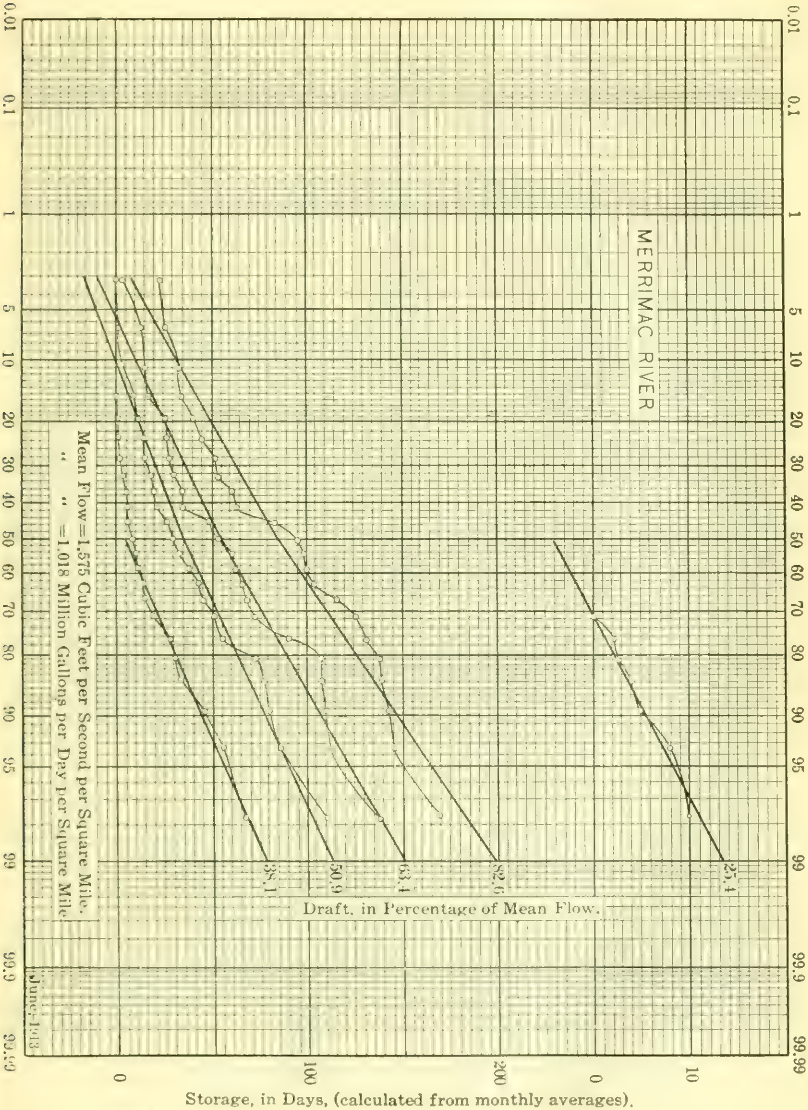

MERRIMAC RIVER
Mean Flow = 1.575 Cubic Feet per Second per Square Mile.
" " = 1.018 Million Gallons per Day per Square Mile.
Draft, in Percentage of Mean Flow.
38.1
50.9
63.4
82.6
25.4
0.01
0.1
1
5
10
20
30
40
50
60
70
80
90
95
99
99.9
99.99
0
100
200
0
10
June 1913
Storage, in Days, (calculated from monthly averages).

FIG. 12.

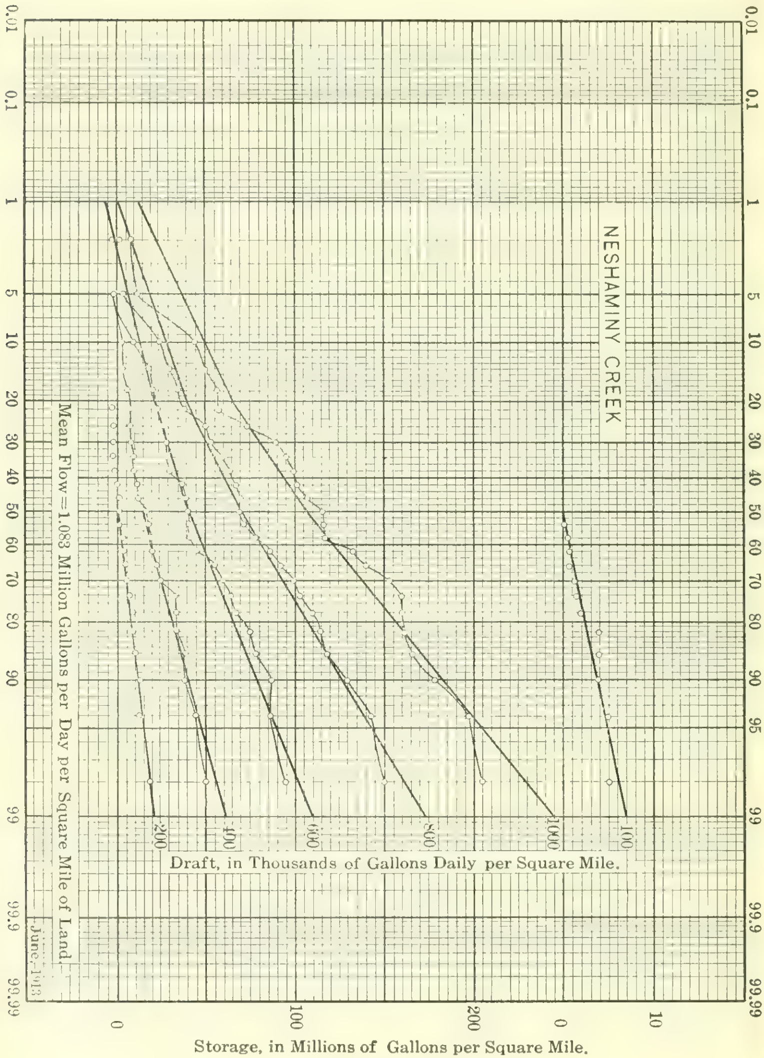

NESHAMINY CREEK
Mean Flow = 1.083 Million Gallons per Day per Square Mile of Land.
Draft, in Thousands of Gallons Daily per Square Mile.
200
400
600
800
1000
100
June, 1913
0.01
0.1
1
5
10
20
30
40
50
60
70
80
90
95
99
99.9
99.99
0
100
200
0
10
Storage, in Millions of Gallons per Square Mile.

FIG. 14.

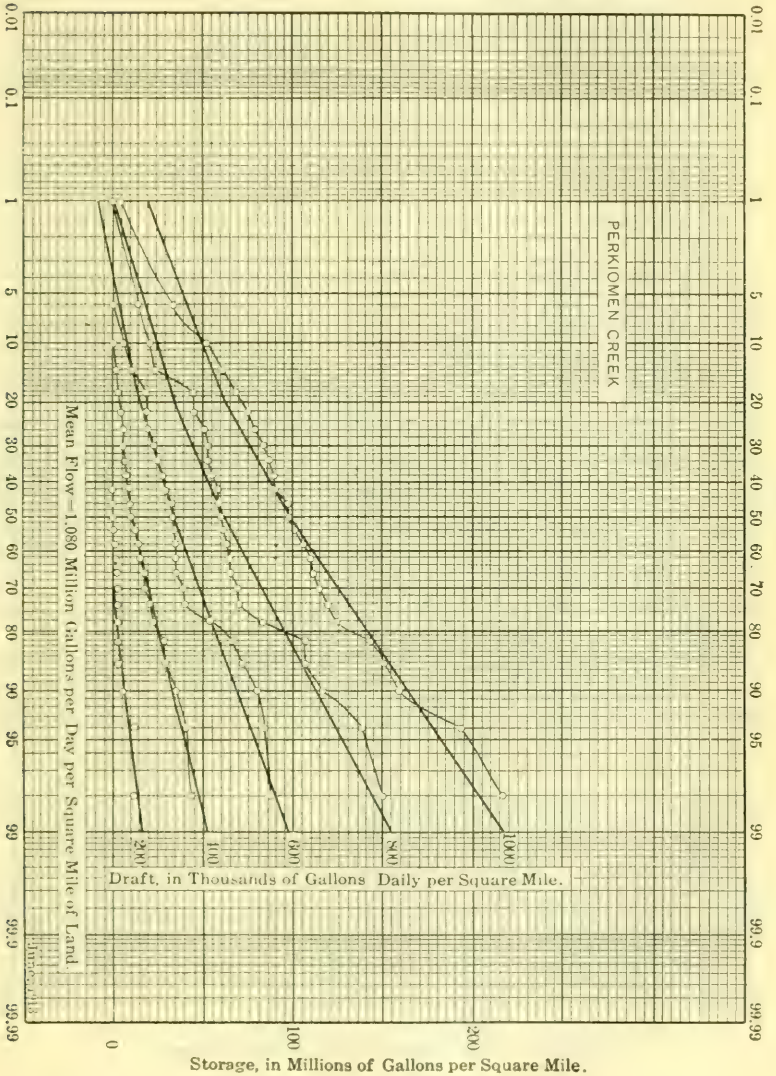

PERKIOMEN CREEK
Mean Flow=1.080 Million Gallons per Day per Square Mile of Land.
Draft, in Thousands of Gallons Daily per Square Mile.
200
400
600
800
1000
Storage, in Millions of Gallons per Square Mile.
0
100
200
0.01
0.1
1
5
10
20
30
40
50
60
70
80
90
95
99
99.9
99.99

Fig. 15.

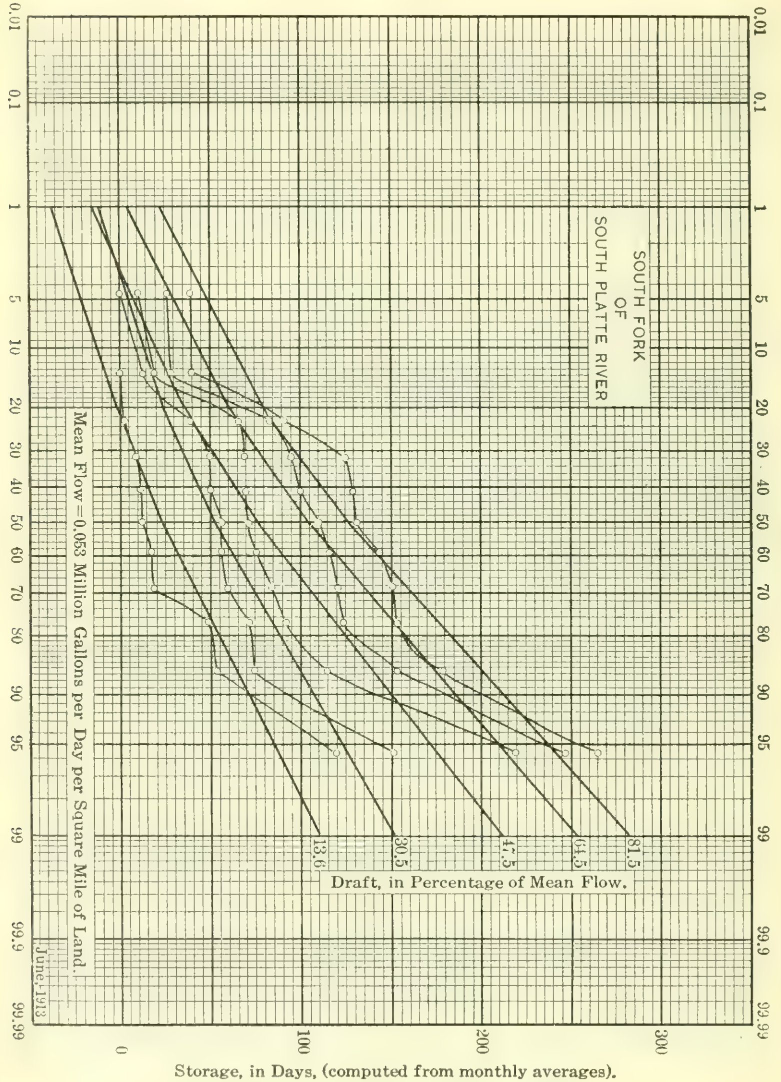

SOUTH FORK
OF
SOUTH PLATTE RIVER
Mean Flow = 0.053 Million Gallons per Day per Square Mile of Land.
June, 1913
Draft, in Percentage of Mean Flow.
13.6
30.5
47.5
64.5
81.5
0.01
0.1
1
5
10
20
30
40
50
60
70
80
90
95
99
99.9
99.99
0
100
200
300
Storage, in Days, (computed from monthly averages).

FIG. 16.

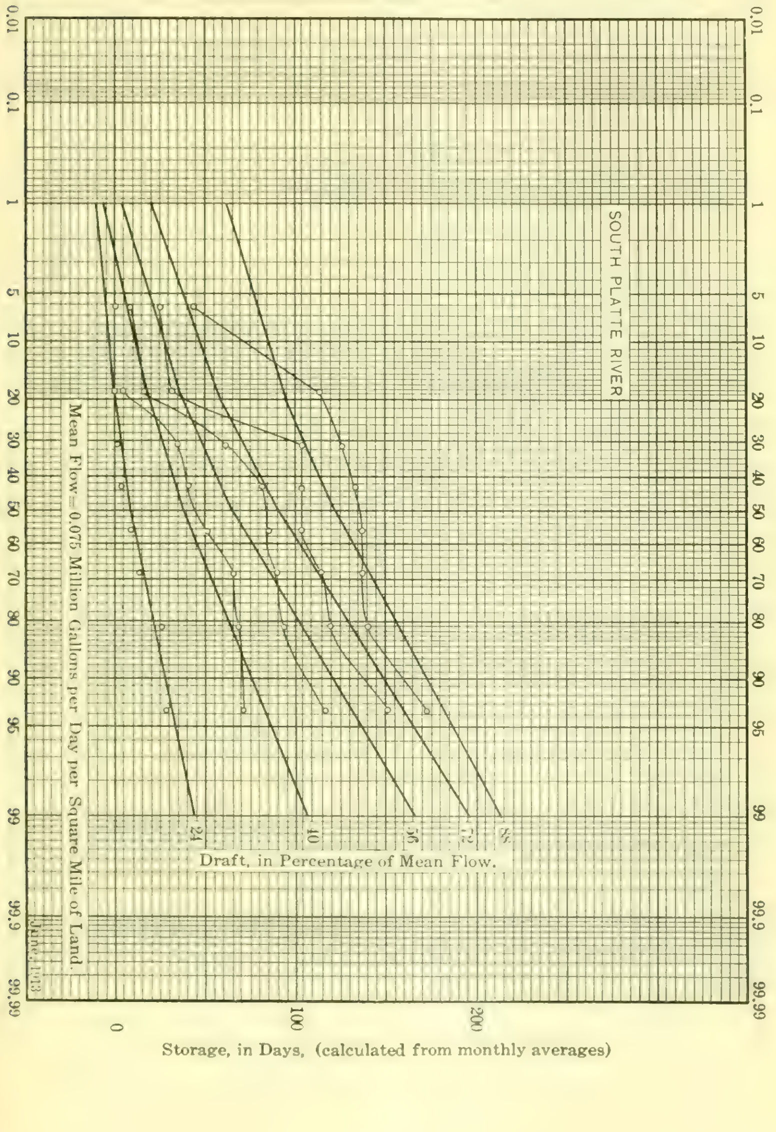

SOUTH PLATTE RIVER
Mean Flow = 0.075 Million Gallons per Day per Square Mile of Land.
Draft, in Percentage of Mean Flow.
24
40
56
72
88
June, 1913
0.01
0.1
1
5
10
20
30
40
50
60
70
80
90
95
99
99.9
99.99
0
100
200
Storage, in Days, (calculated from monthly averages)

Fig. 17.

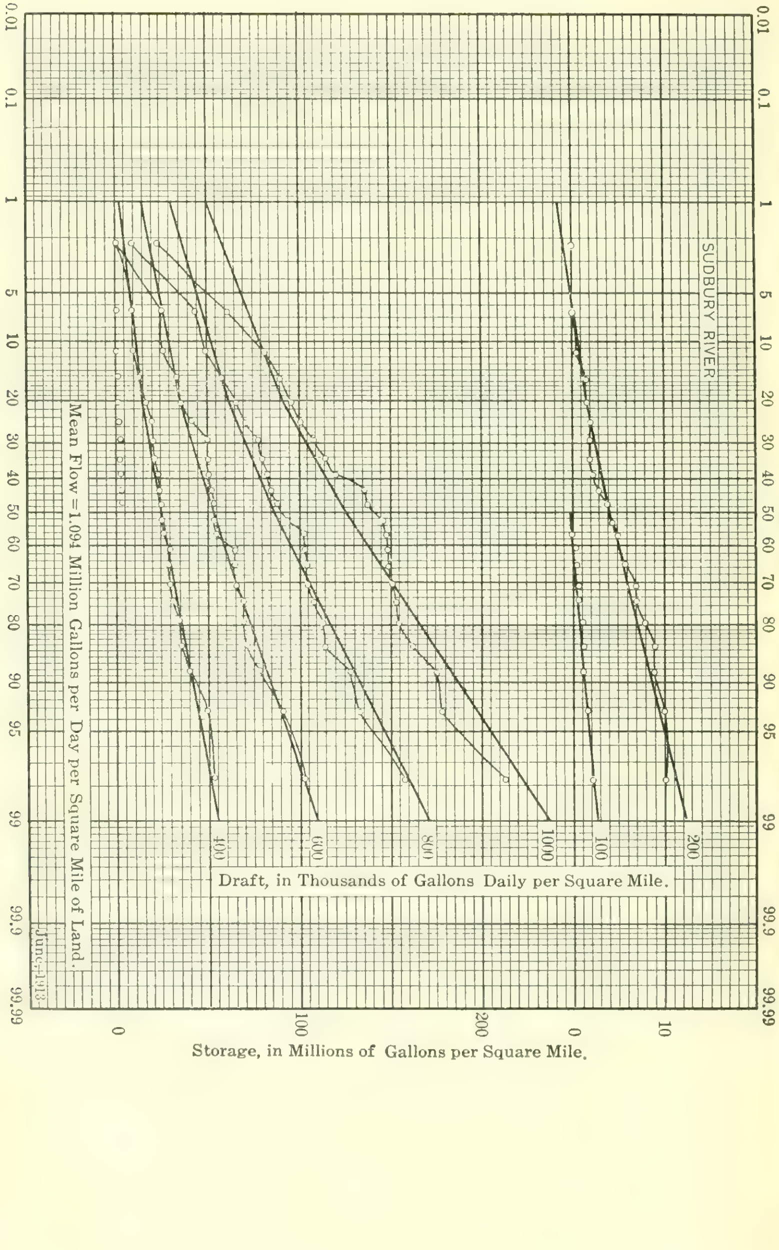

SUDBURY RIVER
Mean Flow = 1.094 Million Gallons per Day per Square Mile of Land.
Draft, in Thousands of Gallons Daily per Square Mile.
400
600
800
1000
100
200
Storage, in Millions of Gallons per Square Mile.
0
100
200
0
10
0.01
0.1
1
5
10
20
30
40
50
60
70
80
90
95
99
99.9
99.99
June-1913

FIG. 18.

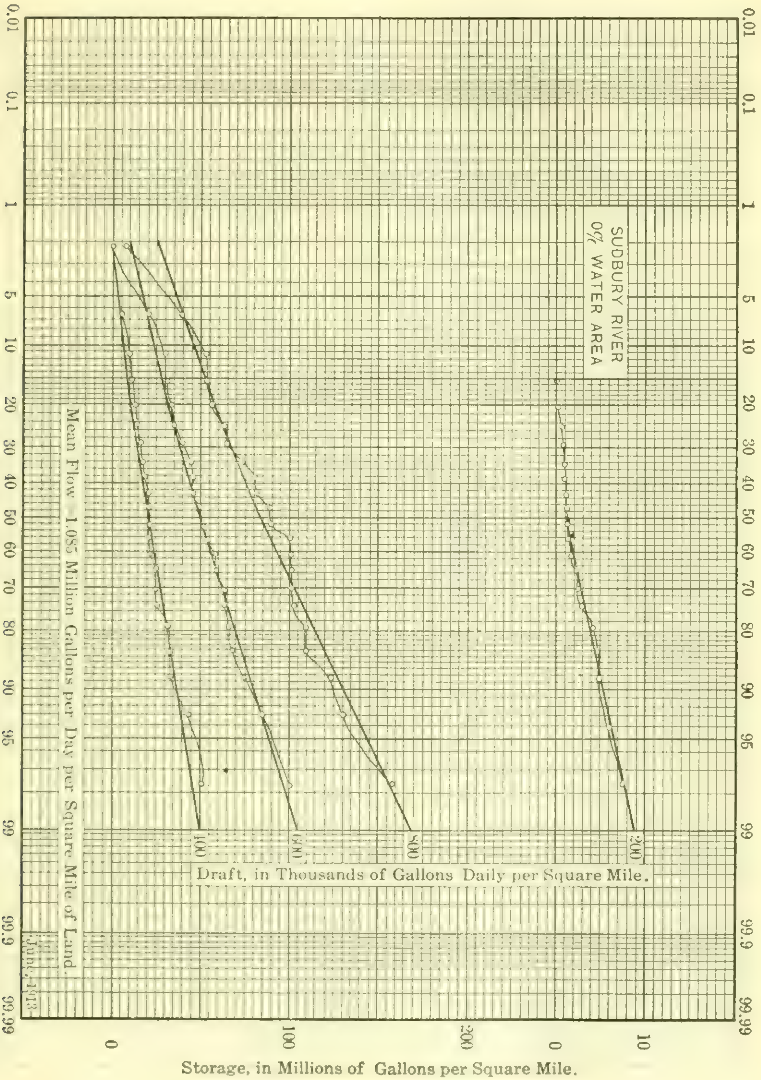

SUDBURY RIVER
0% WATER AREA
Mean Flow 1.085 Million Gallons per Day per Square Mile of Land.
Draft, in Thousands of Gallons Daily per Square Mile.
400
600
800
200
June, 1913
0.01
0.1
1
5
10
20
30
40
50
60
70
80
90
95
99
99.9
99.99
0
100
200
0
10
Storage, in Millions of Gallons per Square Mile.

FIG. 19.

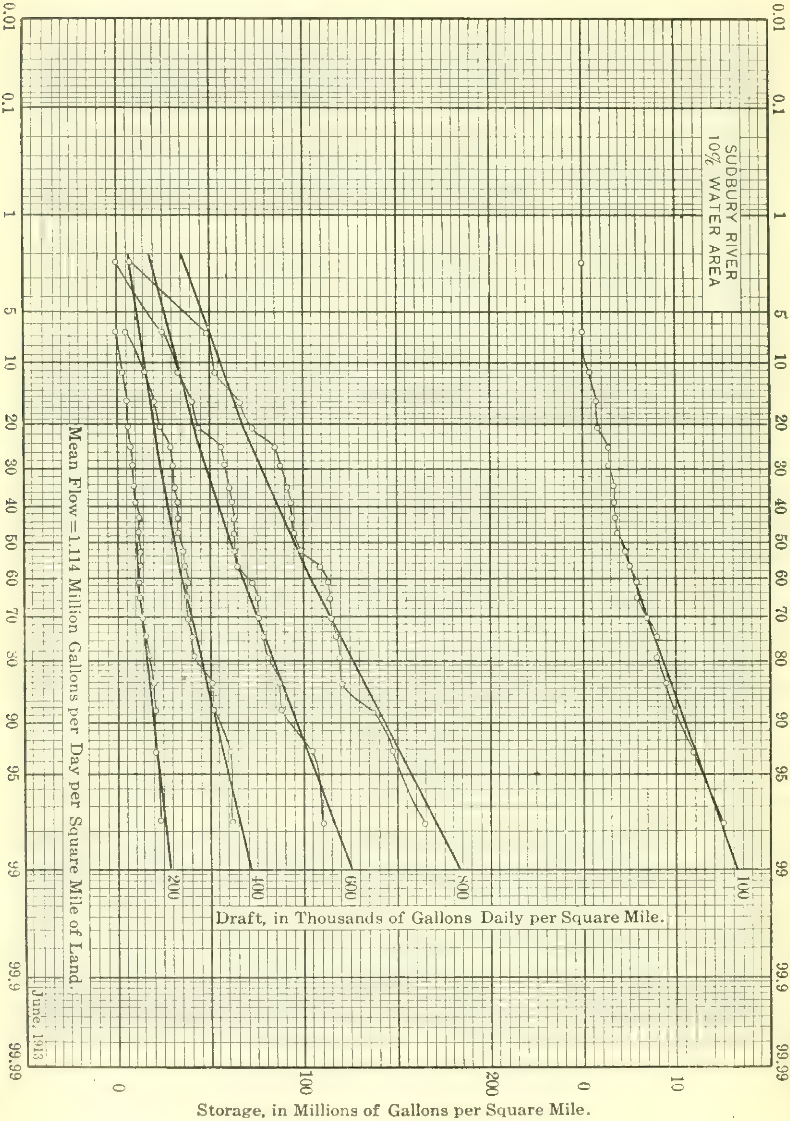

SUDBURY RIVER
10% WATER AREA
Mean Flow = 1.114 Million Gallons per Day per Square Mile of Land.
Draft, in Thousands of Gallons Daily per Square Mile.
200
400
600
800
100
0.01
0.1
1
5
10
20
30
40
50
60
70
80
90
95
99
99.9
99.99
0
100
200
0
10
Storage, in Millions of Gallons per Square Mile.
June, 1913

FIG. 20.

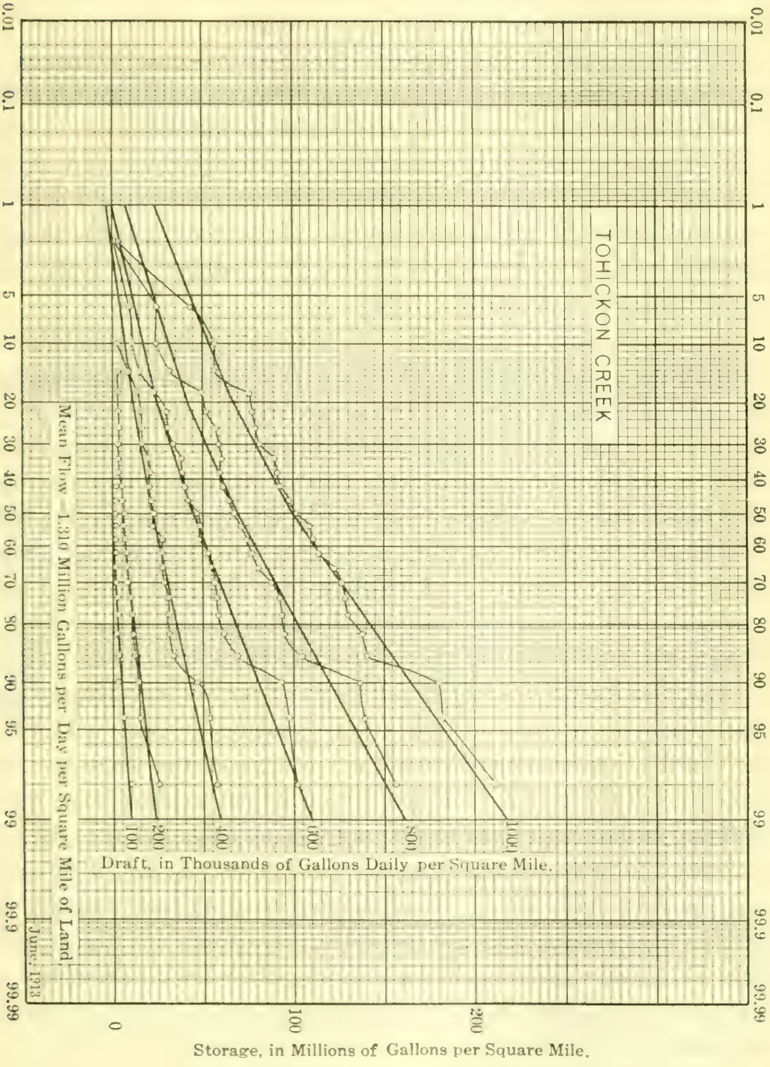

TOHICKON CREEK
Mean Flow 1.310 Million Gallons per Day per Square Mile of Land
June, 1913
Draft, in Thousands of Gallons Daily per Square Mile.
100
200
400
600
800
1000
Storage, in Millions of Gallons per Square Mile.
0
100
200
0.01
0.1
1
5
10
20
30
40
50
60
70
80
90
95
99
99.9
99.99

FIG. 21.

Definition of a Dry Year.—Dry years recur at intervals. The drier the year the longer is the probable interval of its recurrence. For intelligent discussion, it is necessary to define a dry year in terms which will designate the degree of dryness.

In this discussion the procedure has been adopted of arranging all the years in a given series in the order of their dryness. The median year in such a series is referred to as the "50% year". The year of such a degree of dryness that 90% of the years are wetter and 10% are drier than it, is called the "90% dry year", and the year such that 99% of all the years are wetter and 1% drier than it, is called the "99% dry year". Years thus defined are types. No one actual year is meant.

Dry years may be classified with reference to the quantities of rainfall, the quantities of run-off, or the quantities of storage required to maintain certain drafts. Arranging all the years in series in the order of dryness on these different bases will not always place them in the same order. One year may be the driest with reference to rainfall, another with reference to run-off, and still another with reference to the maximum storage required. In this discussion such differences are overlooked, and the 90% dry year is considered as a type and always refers to the year defined as above with reference to whatever matter may be under investigation at the time.

Error by Using Monthly Results.—Thus far, all calculations have been made on a basis of the average monthly flows. Obviously, there will be fluctuations in flow in the days of the months at the beginning of the period of depletion, and in the month during which depletion culminates, which are not represented by the monthly averages. In order to determine how much should be added for daily variations in flow within these months, the Manhan records, for which daily records were also available, were used, and the calculations were made again on the basis of the daily flows. These figures, compared with those based on the monthly average results, are given in Table 2.

There is a slight tendency for the larger figures to occur in the drier years, so that, from a dry-year standpoint, the correction should be above the general average of 8.2 days. Nine is selected as a cor-

rection to be added to all monthly figures. This will be called the "daily storage".

Effect of Using the Monthly Basis on the Rest of the Calculation.— It is found that the storage required, on the basis of the monthly average figures which have been used in this and in most prior investigations, gives too little storage for periods ranging from 0 to 18 days, and averaging 9 days. The quantity of excess storage for each year within these limits is a matter of chance. It depends mainly on whether the storm that terminates the drought and commences to refill the reservoir occurs early or late in the calendar month.

TABLE 2.—ADDITIONAL NUMBER OF DAYS' STORAGE REQUIRED WHEN DAILY FLOWS INSTEAD OF MONTHLY AVERAGES FOR THE MANHAN RIVER ARE USED.

Year.	For Drafts, in Gallons per Square Mile of Land Area per Day.			
	400 000	600 000	800 000	1 000 000
1897	2	8	6	4
1898	5	3	5	6
1899	0	0	7	7
1900	5	7	3	5
1901	5	8	9	12
1902	17	8	11	13
1903	5	8	6	7
1904	10	8	12	9
1905	5	5	15	11
1906	12	12	4	5
1907	5	8	12	18
1908	10	8	10	11
1909	7	17	14	16
Average	6.8	7.7	8.8	9.5

The effect of using monthly averages is to introduce an accidental variation, growing out of the method of record and of calculation, in addition to all the natural variations that exist. As the average excess, called daily storage, is known approximately from the foregoing calculation, no large constant error is to be expected in the corrected result. The fact of the additional variation makes all the monthly figures so much more variable, and adds to the difficulty of analyzing them correctly.

If the matter of securing run-off data were to be taken up again, there would be much to be said in favor of weekly averages. The

probable discrepancy between the required storage calculated from the weekly averages and the daily results would be so small that it could be overlooked. The weekly averages would be easier of analysis than the daily results, and would serve all practical purposes. The weeks are also all of the same length, and the slight errors introduced by the fact that the months are not of the same length would be eliminated.

As nearly all the data now available are on a monthly basis, and as the daily records could only be secured and analyzed with great labor (and, in some instances, not at all), this matter is not open for reconsideration at this time. Attention is called to it with the view of raising the question whether in future it would not be better to use the weekly instead of the monthly basis. The weekly basis has been used always for the record of the flow of the Merrimac River, kept by the Essex Company at Lawrence, for the Connecticut River at Holyoke, and the Pequannock River by the City of Newark.

The importance of making the correction for daily results, when monthly records are used for the basis of calculation, will be realized when it is stated that in most cases this correction amounts to more than the allowance for evaporation.

Method of Least Squares.—Some of the methods of least squares have been found to be applicable to the data of flows and storage. Without explaining the methods found in textbooks, the following fundamental definitions may be given:

The "mean" of a series of terms is the arithmetical average of all the terms. The "median" is the middle term of the series. The "variation" of any term is the difference between that term and the mean. The "standard variation" is the square root of the mean square of the variations of all the terms. The "coefficient of variation" is the ratio of the standard variation to the mean. The "average variation" is the arithmetical average of all the variations. The "probable error" is that variation which is exceeded by one-half the variations, or it is the median of the variations.

The standard variation and the coefficient of variation have generally been used as a basis for calculation. As the tables of the curve of normal error are most commonly given in terms of the probable error, it is often necessary to change one to the other. With data following the law of normal error, the ratios between the standard

variation, the average variation, and the probable error are constant, and are as follows:

Standard variation.....	1.000	1.253	1.483
Average variation......	0.798	1.000	1.183
Probable error.........	0.6745	0.8453	1.000

Data to Which This Method is Not Applicable.—This method of analysis cannot be applied safely to any series of results in which there is more than one zero. There are many important series of this character to be investigated. Such series include the storages required to maintain low rates of draft where, in wet years, the natural flow does not fall below the assumed rate of draft, and when, therefore, no storage is required. It also cannot be applied unless all the terms of the series are available. For instance, good data may be at hand as to the flow in a certain number of dry years, but without corresponding data for intervening years of average, or more than average, flow. For both these cases other methods of handling the data must be found.

In cases of series where there are several zeros, it is possible to get a fair approximation to the standard variation by dividing the difference between the storage for the 99% year and the 50% year, as determined graphically from the plotting, by 2.6, and to approximate the mean storage by adding 0.1 of the standard variation thus found to the storage for the 50% year. Figures thus obtained are starred in the tables which follow to distinguish them from those found by the ordinary arithmetical procedure. By this approximate method, reliable values are obtained which are needed to round out the study and would not otherwise be available.

The adjusted mean storage computed in this way, of course, is not a true mean; but it bears the relation to that part of the series which is available that the mean of the whole series would bear if it were available. The reason the mean obtained by averaging the actual figures does not bear this relation is that, if the whole series were available, some of the terms would be represented by negative numbers. These negative numbers cannot be computed and are not known, but the fact that they would exist in a theoretically complete series introduces a disturbing element if the actual mean is used.

In Table 3 is presented a concise summary of the storage data taken from Figs. 2 to 21 by the foregoing methods.

TABLE 3.—MONTHLY STORAGE DATA FOR SEVERAL STREAMS. (Each Year by Itself. No Cumulative Storage Included.)

(1) Stream.	(2) Assumed Rate of Draft. Gallons per day per square mile of land area.	(3) Assumed Rate of Draft. As portion of mean flow.	(4) Storage Required, in Days' Flow at Assumed Rate of Draft, with Nine Days Added to Monthly Figures to Cover Daily Fluctuations. Mean.	(5) Storage Required, in Days' Flow at Assumed Rate of Draft, with Nine Days Added to Monthly Figures to Cover Daily Fluctuations. In 95% year.	(6) Standard variation in days' storage.
Wachusett, actual	200 000	0.174	11*	46	20.2*
	400 000	0.348	40	89	27.0
	600 000	0.521	66	126	34.8
	800 000	0.695	88	157	39.0
	1 000 000	0.870	110	187	43.0
Wachusett, no water area	200 000	0.176	7*	17	5.0*
	400 000	0.352	24*	71	28.1*
	600 000	0.528	58	112	30.7
	800 000	0.704	82	145	36.4
Wachusett, 0.1 sq. mile water area	200 000	0.171	23*	88	38.5*
	400 000	0.342	53	111	32.8
	600 000	0.513	75	141	38.5
	800 000	0.684	95	165	40.8
Bear Creek	56 000	0.300	1*	32	17.7*
	75 000	0.400	31	68	21.2
	94 000	0.500	57	100	24.2
	112 000	0.600	83	127	26.1
	150 000	0.800	131	193	35.4
Catskill streams	100 000	0.071	10*	29	11.5*
	200 000	0.143	31*	60	17.3*
	400 000	0.286	69	117	27.8
	600 000	0.428	94	152	33.4
	800 000	0.572	112	174	36.1
	1 000 000	0.715	125	190	38.1
Croton, actual	100 000	0.087	3*	40	22.4*
	200 000	0.174	17*	69	28.9*
	400 000	0.348	44*	124	46.2*
	600 000	0.522	72*	154	47.5*
	800 000	0.695	93	178	49.0
Croton, no water area	200 000	0.176	7*	48	25.0*
	400 000	0.352	38*	115	44.2*
	600 000	0.527	71*	154	48.0*
	800 000	0.703	91	175	49.0
	1 000 000	0.870	108	200	52.0
Croton, 0.1 sq. mile water area	100 000	0.085	33*	110	25.7*
	200 000	0.169	44*	130	50.0*
	400 000	0.338	64*	150	50.0*
	600 000	0.507	82*	174	52.6*
	800 000	0.676	102	193	52.2
Gunpowder	200 000	0.220	—10*	9	11.6*
	400 000	0.439	— 5*	62	40.3*
	600 000	0.658	30*	100	41.0*
	800 000	0.877	65	147	46.5
Hudson†	324 000	0.285	7*	36	17.0*
	454 000	0.400	22*	71	28.5*
	648 000	0.570	47	106	34.4
	775 000	0.684	63	129	38.6
	905 000	0.796	77	152	43.2

* Adjusted values which have been inferred from the line drawn to represent the data.
† Includes water area.

TABLE 3.—(*Continued.*)

(1) Stream.	(2) Assumed Rate of Draft. Gallons per day per square mile of land area.	(3) Assumed Rate of Draft. As portion of mean flow.	(4) Storage Required, in Days' Flow at Assumed Rate of Draft, with Nine Days Added to Monthly Figures to Cover Daily Fluctuations. Mean.	(5) Storage Required, in Days' Flow at Assumed Rate of Draft, with Nine Days Added to Monthly Figures to Cover Daily Fluctuations. In 95% year.	(6) Standard variation in days' storage.
Manhan	200 000	0.152	10*	33	13.1*
	400 000	0.304	38*	99	35.6*
	600 000	0.455	61	132	41.5
	800 000	0.607	82	165	48.1
	1 000 000	0.760	99	186	51.8
Merrimac †	259 000	0.254	6*	17	6.7*
	388 000	0.381	16*	66	29.3*
	519 000	0.509	47	100	30.2
	646 000	0.634	67	132	37.2
	842 000	0.826	97	175	44.3
Neshaminy	100 000	0.092	12*	59	27.0*
	200 000	0.184	32*	90	34.6*
	400 000	0.369	56*	130	43.1
	600 000	0.554	84	160	44.0
	800 000	0.738	104	190	48.8
	1 000 000	0.924	122	214	53.0
Perkiomen	200 000	0.185	—2*	59	36.5*
	400 000	0.370	43*	109	38.5*
	600 000	0.555	70	141	40.2
	800 000	0.740	91	169	44.1
	1 000 000	0.926	112	192	45.5
South Fork of South Platte	7 200	0.136	36*	94	33.2*
	16 200	0.305	66	133	37.2
	25 000	0.475	90	181	52.5
	34 000	0.645	119	219	57.4
	43 000	0.815	141	246	60.3
South Platte	18 000	0.240	18*	43	13.8*
	30 000	0.400	45	96	26.1
	42 000	0.560	70	146	35.7
	54 000	0.720	92	175	40.8
Sudbury, actual	100 000	0.091	9*	28	10.8*
	200 000	0.183	31*	59	16.0*
	400 000	0.366	73	125	30.7
	600 000	0.548	101	164	37.3
	800 000	0.732	122	192	40.4
	1 000 000	0.915	139	215	43.2
Sudbury, no water area	200 000	0.184	16*	42	15.0*
	400 000	0.368	63	114	28.8
	600 000	0.553	94	157	36.0
	800 000	0.736	117	188	40.8
Sudbury, 0.1 sq. mile water area	100 000	0.090	56*	139	46.4*
	200 000	0.180	67*	124	32.7*
	400 000	0.359	95	159	37.3
	600 000	0.539	116	187	41.4
	800 000	0.718	132	205	42.7
Tohickon	100 000	0.076	13*	79	38.5*
	200 000	0.152	42*	99	32.7*
	400 000	0.305	69	130	35.6
	600 000	0.458	87	160	42.3
	800 000	0.610	100	178	44.4
	1 000 000	0.764	115	193	44.7

* Adjusted values which have been inferred from the line drawn to represent the data.
† Includes water area.

The figures in Table 3 have been plotted, forming three diagrams. The assumed rate of draft, as a fraction of the mean flow, as shown in Column 3, is used as a base for each. In Fig. 22 are plotted the figures in Column 4, showing the mean storage required in days' flow for each of the streams. In Fig. 23 the figures in Column 5 are plotted, showing the storage required in a 95% dry year, and Fig. 24 shows the figures in Column 6 for standard variation in days' storage. In plotting these results, the corrected figures for no water surface for the Sudbury, Croton, and Wachusett are used, as being, on the whole, most suitable for this purpose.

It is seen by inspection of Figs. 22 and 23 that the number of days' storage required in different streams varies considerably, but the lines representing the required storage at different rates of draft are rather strikingly parallel with each other. In other words, an increased rate of draft requires nearly the same increase in the quantity of storage on all the streams. This is shown further in Tables 4, 5, and 6.

TABLE 4.—Difference Between the Average Number of Days' Storage Required at Several Rates of Draft, and the Storage Required for 50% of the Mean Flow for Different Streams for the Mean Year.

Stream.	Number of years in record.	Difference Between Required Storage and Storage at 50 Per Cent.					
		0.20 use.	0.30 use.	0.40 use.	0.60 use.	0.70 use.	0.80 use.
Bear Creek	11	....	56	26	26	50	74
Catskill	17	57	31	14	11	21	30
Croton	45	55	38	19	13	25	36
Gunpowder	29	....	....	....	16	32	48
Hudson	23	....	27	14	15	29	41
Manhan	14	48	30	14	14	25	36
Merrimac	23	45	35	25	16	32	48
Neshaminy	25	42	28	15	13	24	34
Perkiomen	25	60	36	15	13	25	36
South Fork	11	46	29	15	17	32	45
South Platte	8	29	32	15	15	29	46
Sudbury	22	66	40	18	14	26	38
Tohickon	25	41	23	11	8	18	27
Wachusett	15	44	34	20	15	28	42
Weighted average	293	51.1	33.5	17.0	14.1	27.2	39.4

Table 7 shows the number of days' storage required to maintain a 50% draft in an average year and in a 95% dry year, and the additional quantity required for the latter over the former.

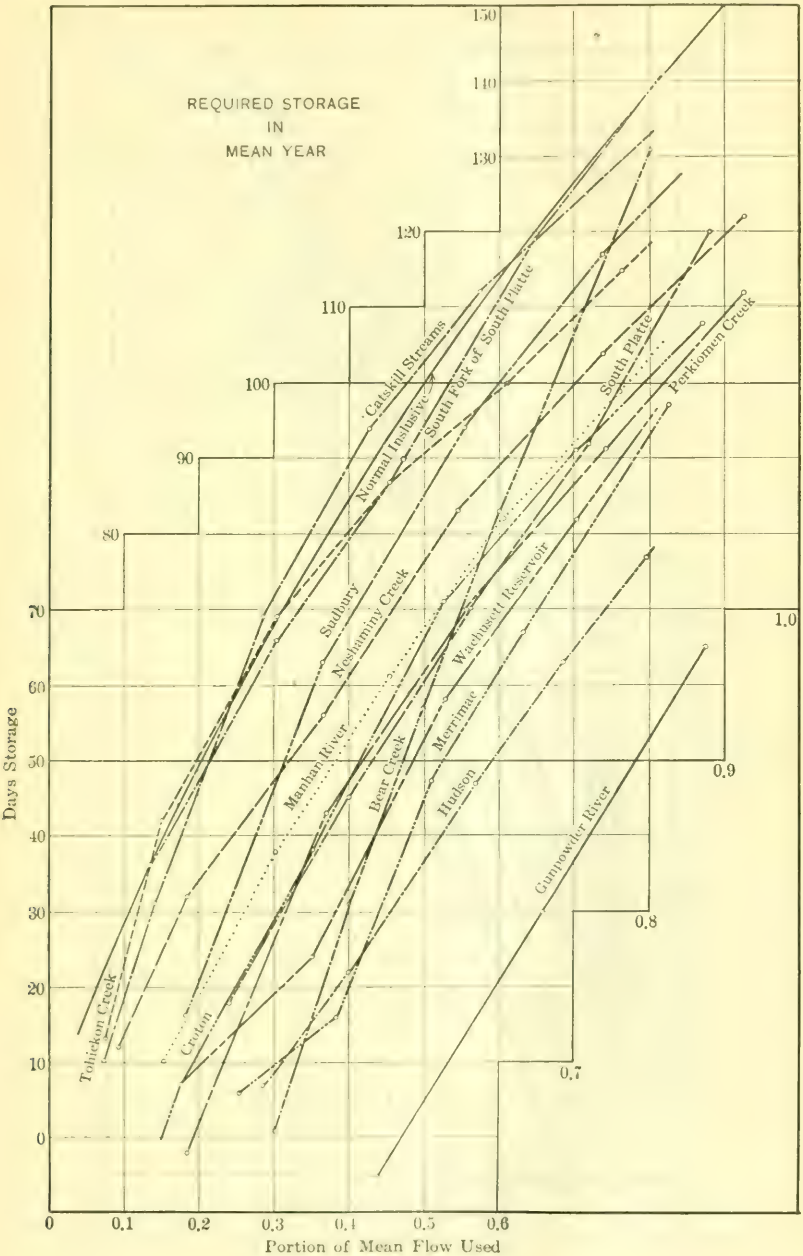

REQUIRED STORAGE
IN
MEAN YEAR
Days Storage
Portion of Mean Flow Used
Catskill Streams
Normal Inslusive
South Fork of South Platte
South Platte
Perkiomen Creek
Sudbury
Neshaminy Creek
Wachusett Reservoir
Manhan River
Bear Creek
Merrimac
Hudson
Gunpowder River
Croton
Tohickon Creek
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

FIG. 22.

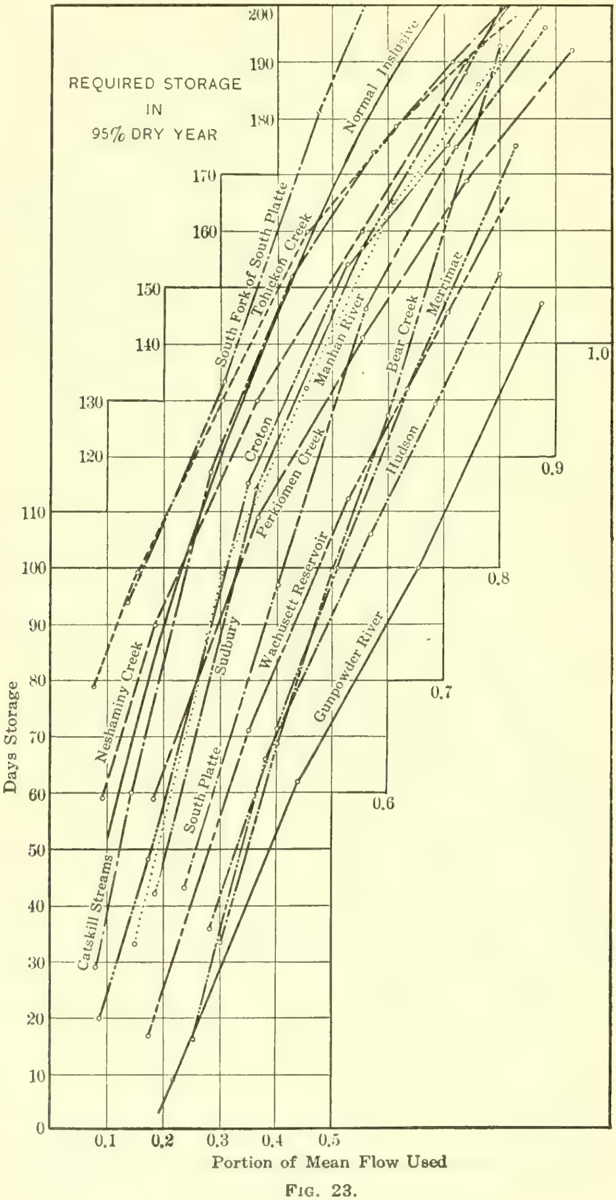

REQUIRED STORAGE
IN
95% DRY YEAR
Days Storage
Portion of Mean Flow Used
South Fork of South Platte
Tohickon Creek
Normal Inclusive
Manhan River
Bear Creek
Merrimac
Croton
Perkiomen Creek
Hudson
Neshaminy Creek
Sudbury
Wachusett Reservoir
Gunpowder River
South Platte
Catskill Streams

FIG. 23.

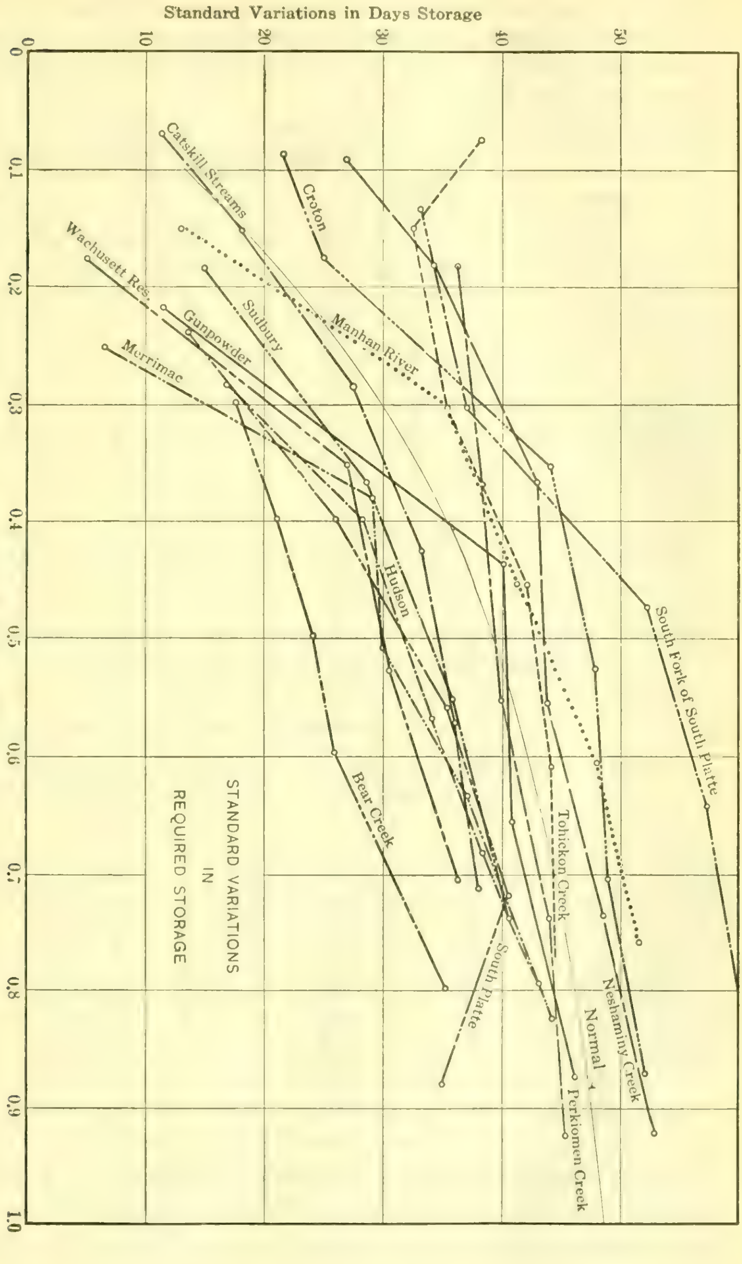

Standard Variations in Days Storage
0
10
20
30
40
50
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Catskill Streams
Croton
Wachusett Res.
Sudbury
Manhan River
Gunpowder
Merrimac
Hudson
South Fork of South Platte
Tohickon Creek
Bear Creek
South Platte
Neshaminy Creek
Normal
Perkiomen Creek
STANDARD VARIATIONS
IN
REQUIRED STORAGE
Portion of Mean Flow Used

Fig. 24.

TABLE 5.—DIFFERENCE BETWEEN THE AVERAGE NUMBER OF DAYS' STORAGE REQUIRED AT SEVERAL RATES OF DRAFT, AND THE STORAGE REQUIRED FOR 50% OF THE MEAN FLOW FOR SEVERAL STREAMS, FOR THE 95% DRY YEAR.

Stream.	Number of years in record.	Difference Between Required Storage and Storage at 50 Per Cent.					
		0.20 use.	0.30 use.	0.40 use.	0.60 use.	0.70 use.	0.80 use.
Bear Creek	11	100	68	32	27	60	93
Catskill	17	81	43	18	14	25	36
Croton	45	92	54	23	14	26	38
Gunpowder	29	68	44	20	17	36	58
Hudson	23	81	51	20	21	41	62
Manhan	14	89	45	22	21	36	50
Merrimac	23	98	64	28	25	49	71
Neshaminy	25	58	36	16	17	33	47
Perkiomen	25	70	42	18	16	31	44
South Fork	11	77	55	27	23	42	57
South Platte	8	98	65	31	26	44	58
Sudbury	22	96	57	24	20	38	54
Tohickon	25	57	36	17	11	21	31
Wachusett	15	82	51	24	19	38	57
Weighted average	293	80.6	49.6	22.0	18.2	35.2	51.7

TABLE 6.—STANDARD VARIATIONS IN STORAGE IN TERMS OF DAYS' FLOW FOR SEVERAL STREAMS AT VARIOUS RATES OF DRAFT.

Stream.	Number of years in record.	Standard Variation in Days' Flow.						
		0.20 use.	0.30 use.	0.40 use.	0.50 use.	0.60 use.	0.70 use.	0.80 use.
Bear Creek	11	....	18	21	24	26	31	35
Catskill	17	21	28	32	35	37	38	39
Croton	45	28	38	45	47	48	49	50
Gunpowder	29	9	22	36	40	41	42	45
Hudson	23	....	18	28	32	35	39	43
Manhan	14	20	35	39	43	48	50	53
Merrimac	23	....	15	29	30	35	40	43
Neshaminy	25	35	40	43	44	46	48	50
Perkiomen	25	37	38	39	40	41	43	44
South Fork	11	35	37	46	53	56	58	60
South Platte	8	12	19	26	32	37	40	38
Sudbury	22	16	24	30	34	37	40	42
Tohicken	25	34	35	40	42	44	45	45
Wachusett	15	8	21	28	30	33	36	39
Weighted average.	293	24.4	29.0	36.0	38.0	41.1	43.2	45.3

Normal Storage Diagram.—The data in Tables 4 to 7 may be combined to form a composite storage curve representing all the data. The variations in the several cases do not differ widely, but the

absolute quantities do, depending on natural storage and other conditions which are not the same for different streams. The composite curve may be an average or an inclusive one. The latter is selected, and 100 days' storage for a use equal to 50% of the normal flow is taken as the starting point. This covers all but one of the figures in Table 7, and is within the probable error of that one. The exact value taken is of no particular significance, as will appear as the method of use is developed. In a 95% dry year the normal storage (Table 7) will be 68 days more than this, or 168 days. Adding or subtracting the normal differences shown in Tables 4 and 5, gives the figures in Table 8.

TABLE 7.

Stream.	Number of years.	Number of Days' Storage Required to Maintain Flow Equal to 50% of Normal.		
		Mean.	95% year.	Difference.
Bear Creek	11	57	100	43
Catskill	17	103	163	60
Croton	45	66	148	82
Gunpowder	29	5	72	67
Hudson	23	36	91	55
Manhan	14	67	142	75
Merrimac	23	45	98	53
Neshaminy	25	62	132	70
South Fork	11	94	186	92
South Platte	8	60	127	67
Sudbury	22	86	144	58
Tohickon	25	91	165	74
Wachusett	15	53	106	53
Weighted average	293	....	....	68

TABLE 8.

Portion which use is of mean flow.	Normal days' storage in average year.	Normal days' storage in 95% dry year.
0.10	(27)	(50)
0.20	49	88
0.30	67	119
0.40	84	145
0.50	100	168
0.60	114	186
0.70	127	203
0.80	139	219
0.90	(150)	(233)
1.00	(160)	(246)

The figures in Table 8 are plotted on probability paper (Fig. 25). The figures for the mean year are plotted on the 54% line, instead of the 50% line, because investigation shows that

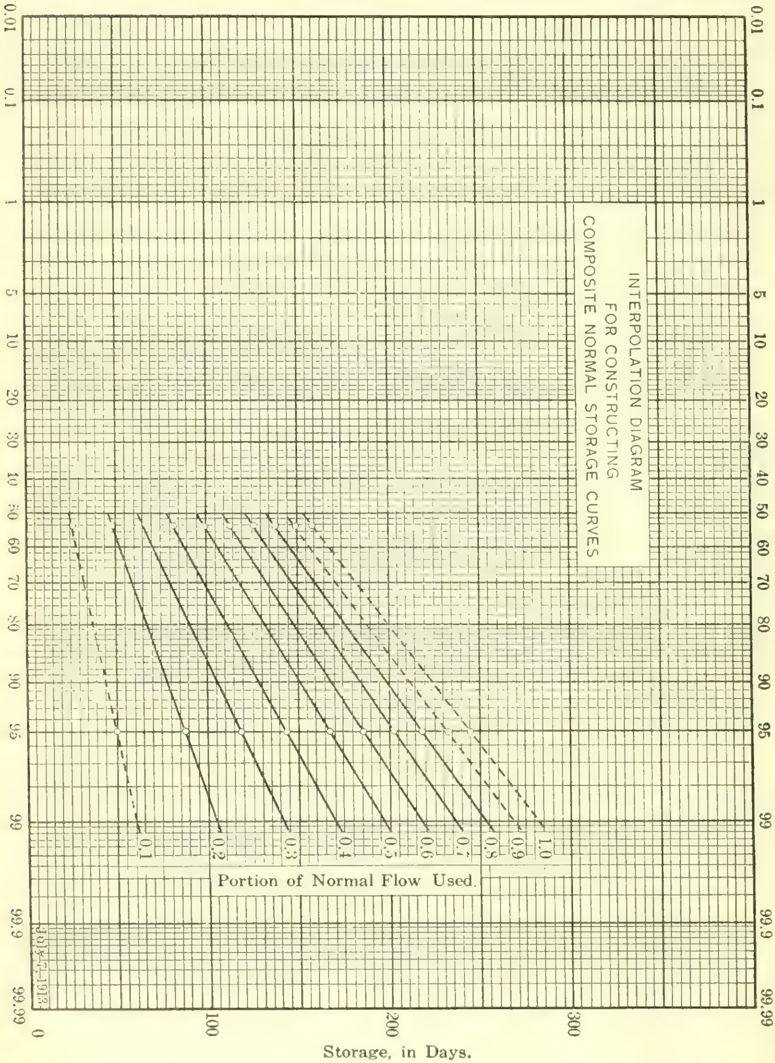

INTERPOLATION DIAGRAM
FOR CONSTRUCTING
COMPOSITE NORMAL STORAGE CURVES
Portion of Normal Flow Used.
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
0.01
0.1
1
5
10
20
30
40
50
60
70
80
90
95
99
99.9
99.99
0
100
200
300
Storage, in Days.

FIG. 25.

about 54% of all the terms are less than the mean. From this diagram the number of days' storage required to maintain the several assumed rates of flow in years of other degrees of dryness may be taken. Values thus found have been used in plotting Fig. 26, which shows the normal inclusive quantity of storage required to maintain various rates of draft, in years of different degrees of dryness. This diagram, from the method of its construction, is above all but a few individual results.

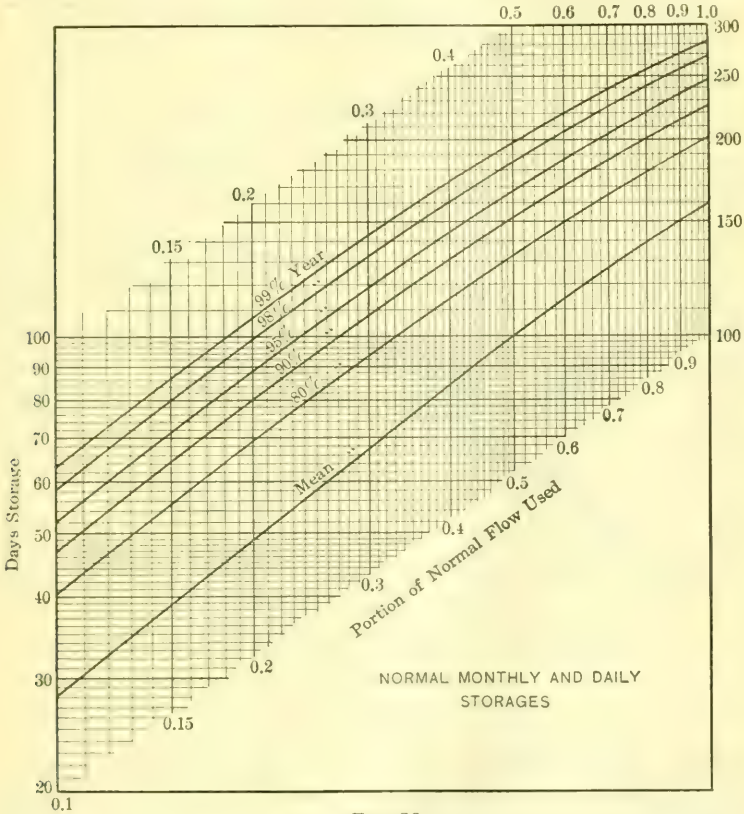
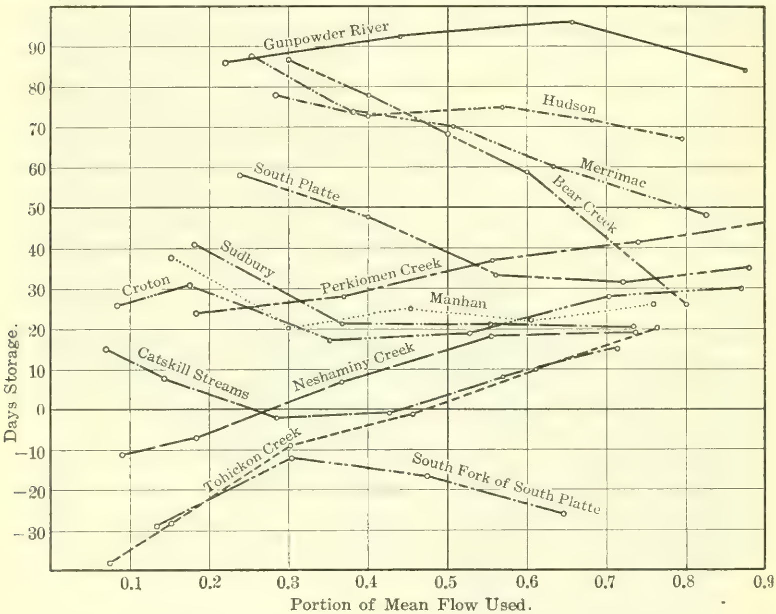


Fig. 26.

The quantity, as shown by the records of various streams, by which the storage actually required falls below the normal storage diagram at various points may be found. Table 9 shows the quantity that they fall below in a 95% dry year, and Fig. 27 shows the difference graphically.

If the normal storage diagram applied strictly to all the records, the figures for Table 9 for each stream at different rates of draft would be constant. This is only approximately the case. The variations represent, in part, accidental variations of the kind that would be found in different parts of a very long record of one stream, and, in part, actual difference in conditions in the different catchment areas, and in their climates and conditions of natural storage, which tend to modify the values of the normal storage diagram. The accidental



QUANTITIES WHICH ACTUAL STORAGES ARE LESS THAN NORMAL STORAGES

Showing effect of ground-water storage and other conditions peculiar to the several areas.

FIG. 27.

variations are considerable. Some of the most striking variations are in the short-term records, and these are to be considered as mainly accidental. The long-term records usually show smaller variations. However, the three Philadelphia streams, Neshaminy, Perkiomen, and Tohickon, show a well-defined tendency to require a greater relative quantity of storage for low rates of draft. This may indicate a greater summer evaporation and a smaller summer run-off, or some variation in seasonal distribution of rainfall. On the other hand, the Merrimac

requires less relative storage for low rates of draft. This may be accounted for in part by the natural lakes on this river, which modify the conditions of run-off by the added evaporation from the water surface, and increase the flow by natural storage in the lakes, which normally runs out gradually during the summer with falling lake level, and tends to maintain the flow.

TABLE 9.—QUANTITY THAT THE ACTUAL MONTHLY STORAGE (CORRECTED FOR DAILY STORAGE) IS LESS THAN THE NORMAL STORAGE DIAGRAM, IN DAYS' STORAGE FOR SEVERAL STREAMS AND RATES OF DRAFT.

95% DRY YEAR.

Stream.	Number of years in record.	Difference Between Actual Required Storage and Normal Storage Diagram.							
		0.20 use.	0.30 use.	0.40 use.	0.50 use.	0.60 use.	0.70 use.	0.80 use.	Average.
Bear Creek......	11	....	87	78	68	59	43	26	64
Catskill...........	17	4	— 2	— 1	4	9	15	....	5
Croton	45	29	21	18	19	23	28	....	23
Gunpowder	29	85	88	91	93	95	94	88	91
Hudson..........	23	....	78	73	75	74	71	67	73
Manhan	14	33	21	24	25	22	25	27	25
Merrimac........	23	....	84	73	70	63	56	50	66
Neshaminy......	25	— 6	2	9	15	19	19	....	10
Perkiomen.......	25	24	26	29	34	38	40	43	33
South Fork......	11	— 22	— 12	— 16	— 19	— 24	— 25	....	— 20
South Platte....	8	....	55	48	39	33	32	33	40
Sudbury.........	22	40	29	22	21	21	21	20	25
Tohickon........	25	— 22	— 10	— 4	2	9	16	....	2
Wachusett.......	15	63	62	62	62	61	59	....	61

The area of water surface makes a substantial difference in the required storage for the lower rates of draft, but much less difference relatively for the higher rates. This is illustrated by Fig. 28, which shows the storage data for the Croton River, using the flows as they naturally occurred, as corrected to represent an area with no water, and as computed for one part of water area for each ten parts of land area, the values for this plotting being taken from Table 3.

Summary as to Monthly and Daily Storage, Excluding Annual Storage.—The foregoing studies relating to the storage required to maintain flows through one year, and excluding all consideration of cumulative storage, show that, after due allowance is made for the constantly recurring fluctuations, depending on rainfall and other conditions, to analyze which no attempt is made, there remains a fairly definite and simple relation between the draft and the required

storage. There is also a fairly definite and simple relation between the available supplies in years of different degrees of dryness and the frequency of the recurrence of such years. These relations may be expressed in a normal storage diagram which shows the storages in terms of days' draft. The storages thus shown are greater than those actually required on any particular stream by a number of days which is nearly constant for that stream, but varies considerably for different streams, as it depends on the natural storage on the catchment area, and other physical conditions of that stream.

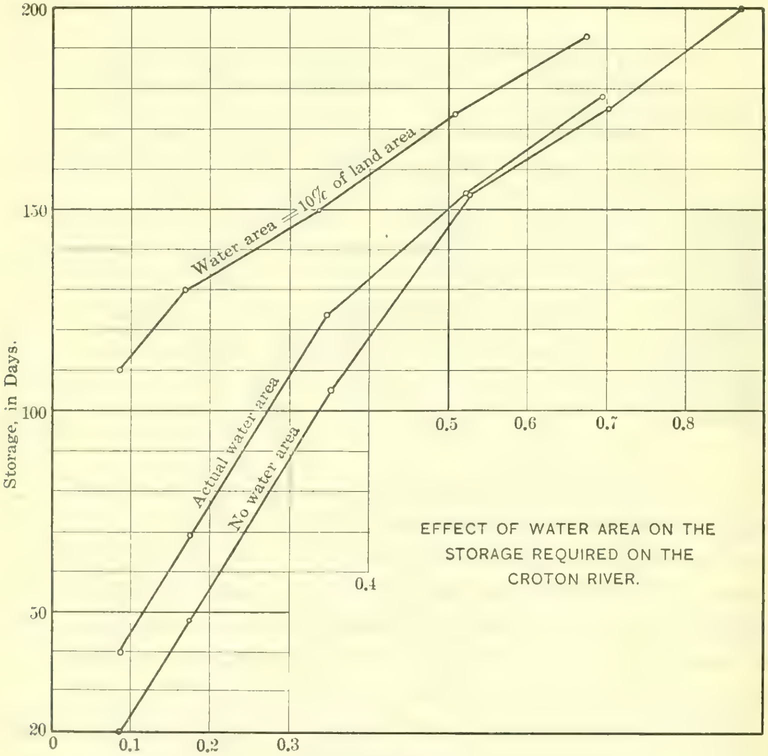


FIG. 28.

This nearly constant quantity can be estimated from the records of a relatively short term of years by finding the mean storages required to maintain one or more assumed rates of draft and subtracting these from the normal storages for the same rates of draft for an

average year. This difference (or the average of several of them) subtracted from the normal storage diagram will give a fair estimate of the storage required under various conditions for that stream, and is probably more accurate than can be made from any but the longest and most carefully kept records of flow for that particular stream.

As to the Application of the Normal Law of Error to Flow and Storage Data.

Discussion of this point has been deferred until the data represented by Figs. 2 to 21, inclusive, could be presented. A study of these diagrams gives an indication of the extent to which the data can be analyzed in this way. If the normal law of error applied strictly, the results for each series would all be found in one straight line. That, of course, is practically impossible. A reasonable approach to a straight line indicates that the data follow the law approximately. In the cases of the longest continued records, the plotted points correspond well with the lines drawn to represent normal conditions. In the records covering shorter periods there are wider fluctuations, owing to the fact that the terms of the series are not numerous enough to have filled in all the intermediate and extreme values that would be found in a long series. In general, the longer the period of record the more closely do the results permit of plotting in a direct line.

To test the matter further, two combination series of results were prepared, showing the variations in terms of the standard variation for each series, first, of the annual flows of each stream for the 300 years, shown in Plate XCVI; second, the quantities of storage, similarly arranged, required to maintain drafts of 600 000 and 800 000 gal., respectively, per square mile of land area for each of the streams for which these figures were available. A summary of the results of these two series is given in Table 10.

The figures of Table 10 are plotted in Fig. 29. The two series correspond well, and a single line is drawn to represent both. No significance is attached to the fact that the two correspond; this is considered to be purely accidental. The line representing these results is a direct line, but not a straight one. Most of the results of each series are below the mean; and the variations upward, though less numerous, are greater in magnitude than the variations downward. The results may be combined further, as in Table 11.

TABLE 10.

(1) Actual variation, in terms of the standard variation.	(2) 300 Terms in Series of Annual Flow.		(3) 402 Terms in Series of Required Storage.		(4) Together: 702 Terms.	
	Number below limit in Column 1.	Percentage.	Number below limit in Column 1.	Percentage.	Number below limit in Column 1.	Percentage.
— 2.5	0	....	1	0.2	1	0.14
— 2.0	0	....	3	0.7	3	0.4
— 1.5	7	2.3	15	3.7	22	3.1
— 1.0	56	18.7	68	17.0	124	17.7
— 0.5	104	34.6	138	34.3	242	34.4
Mean	163	54.3	229	57.1	392	55.8
+ 0.5	218	72.7	275	68.4	493	70.2
+ 1.0	246	82.0	327	81.3	573	81.6
+ 1.5	373	91.0	367	91.2	640	91.2
+ 2.0	288	96.0	391	97.3	679	96.7
+ 2.5	295	98.3	401	99.8	696	99.14
+ 3.0	299	99.7	402	....	701	99.86
+ 3.5	300	100.0	....	....	702	.....

TABLE 11.

Range in standard variations.	Percentage of Terms Outside Range.			
	Below.	Above.	Total.	Computed to follow normal law of error.
0	55.8	44.2	100.0	100.0
$0 - 0.5C$	34.4	29.8	64.2	61.8
$0 - 1.0C$	17.7	18.4	36.1	31.7
$0 - 1.5C$	3.1	8.8	11.9	13.4
$0 - 2.0C$	0.4	3.3	3.7	4.6
$0 - 2.5C$	0.14	0.86	1.00	1.26
$0 - 3.0C$	0.0	0.14	0.14	0.27

In Table 11 the computed and actual variations have been compared. It is seen that the range in combined upward and downward variations agrees as closely as could be expected with the range computed from the normal law of error. The variations upward and downward, taken separately, are not equal. In other words, we have to deal with what is called a skew curve on probability paper. Both ends of this skew curve seem to be nearly straight, with a connecting curve. In drawing the curves for Figs. 2 to 21, inclusive, the ratios in Table 12, obtained from the line in Fig. 29, were used. Straight lines were used to connect these points. No special significance is attached to these figures. Other figures, differing, more or less, from them, would be found from other similar data. The im-

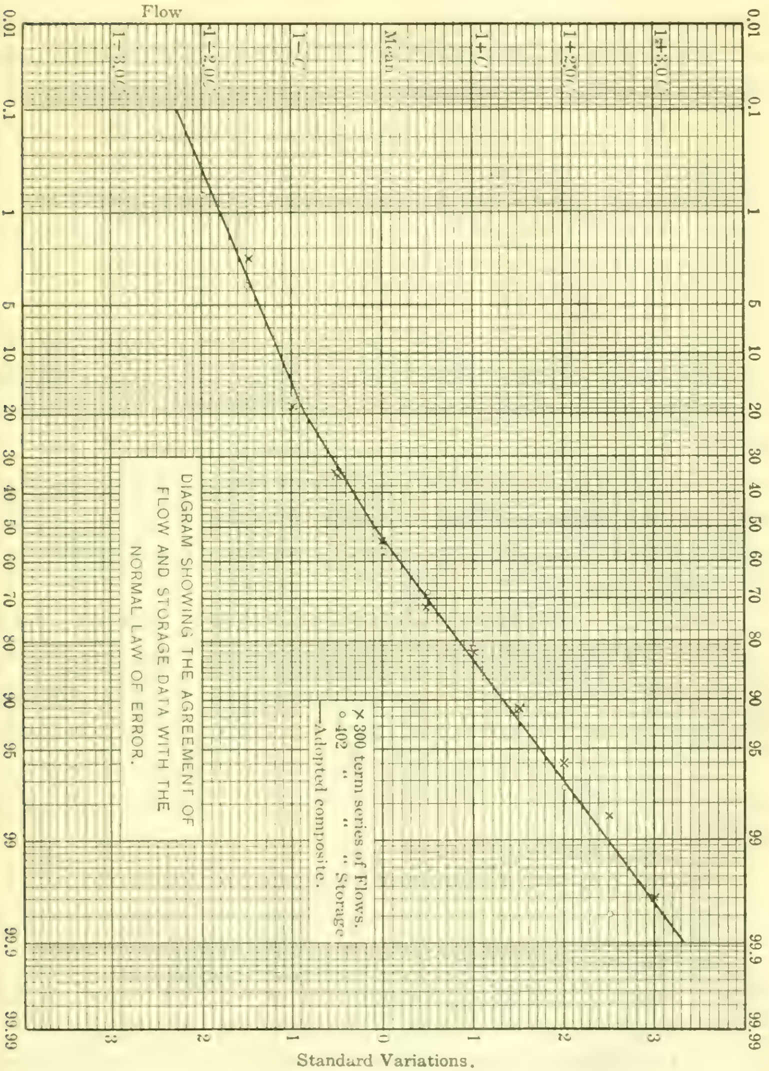

Flow
Mean
DIAGRAM SHOWING THE AGREEMENT OF FLOW AND STORAGE DATA WITH THE NORMAL LAW OF ERROR.
× 300 term series of Flows.
∘ 402 " " " Storage
—Adopted composite.
Standard Variations.

Fig. 29.

portant point is that data of this kind plotted on probability paper are close to a line which is direct and nearly straight at the ends, and when points are thus plotted and a line is drawn to represent them, by the graphical method herein used, it will represent the data and the probability of recurrence of certain values with as much accuracy as can be now expected.

TABLE 12.

Percentage of results smaller than limit.	Actual variation in terms of the standard variation.
1	−1.83
20	−0.88
50	−0.10
99	+2.50

Much more numerous data, covering many times longer periods, would be required to settle finally whether the law of error, as used in this way, is strictly applicable to long-term records.

It is clear that, using the normal law of error in a graphical way, with probability paper, eliminates errors growing out of the unequal variation above and below the mean, which would result from consideration of the data by arithmetical methods.

Although the evidence at hand is not conclusive that the method used is rigorously applicable to longer terms, and from the nature of the case it cannot be, it may be stated that, as far as the data go, the agreement is satisfactory, and the basis may be accepted as representing the conditions likely to occur during a long term of years with a smaller probable error than would result by any other procedure now available.

Storage Required to Equalize Variations in Annual Flows.

The discussion thus far has related to the storage required to equalize the flow during the months and days of any one year. With the eastern streams investigated, the annual flow will fall to 75% or less, of the mean annual flow, once in 10 years, on an average, and to 55% of the normal, or less, once in 100 years. With western streams, the range is greater. It is possible, by storage, to use more water at all times than flows in a dry year, but to do this it is necessary to carry water over from wet years to make it available in dry ones.

In the following paragraphs "annual flow" means the average of observations during a period of one year, stated either in millions of gallons per day, or cubic feet per second per square mile, or as a fraction of the mean annual flow. "Mean annual flow" is the average of the annual flows for the whole record period.

On Plate XCVI are plotted the relative annual flows of fourteen streams, the records of which have been combined into a single series of 300 years. As the mean annual flows for the several streams are different, the figures for each have been taken as the ratio of the annual flow for each year to the mean annual flow for that stream.

The coefficient of variation for the annual flows has been computed separately for each stream, and the figures are entered at the top of the diagram. The records of the several streams are placed in the order of the coefficients of variation, beginning with the Hudson, which has the lowest, and ending with the South Fork of the South Platte, which has the highest.

It is obvious that the storage required to balance annual fluctuations in flow will increase with the coefficient of variation for the mean annual flows. It is not unlikely that the coefficient of variation may be used as a basis for measuring the storage in such a way that the results will be general, and will apply equally to all the streams within the range coverèd by this study.

It is believed that the top part of the area included by the curve of flow, as plotted in the lower portion of the diagram, Plate XCVI, that being taken broad enough to cover all the variations that occur, is the only part that needs consideration; and that the lower part, below the minimum annual flow, goes forward, in any event, with regularity through all years, and requires no storage to maintain it from year to year. Increasing or decreasing the quantity of this constant lower part has practically the effect of decreasing or increasing the coefficient of variation, but is without effect on the standard variation. With this condition in mind, the unit of storage was selected as the standard variation in annual flow. This is obtained directly from the records of annual flows, or otherwise by multiplying the mean annual flow by the coefficient of variation.

The rate of draft must also be expressed in a form in which the coefficient of variation will be an element. The method selected was

to compute the storage required for drafts equal to the mean annual flow, less a certain part of a "standard variation". These may be represented conveniently by the formula:

Mean Annual Flow $\times$ [1 — a $\times$ (Coefficient of Variation)].

Method of Calculating Annual Storage.—The calculation is carried out by assuming an indefinitely large reservoir, full at the beginning of the record period, with a constant assumed rate of draft from it, and finding the depletion, if any, at the end of the first year, with the flows occurring as shown by the records, and at the end of the second year, and of every year for the whole period. In carrying this out, monthly flows are disregarded; only mean annual flows are taken into account.

The rate of draft corresponding to the mean annual flow less 0.4, 0.6, 0.8, 1.0, 1.2, and 1.5 standard variation in annual flow, and also the value of one unit of storage, is calculated for each stream separately, and these are used in examining the terms in the series derived from the record of that stream. The required storage, that is to say, the computed depletion of an indefinitely large reservoir at the end of each year, is then stated in units of storage. When deficiency of storage is indicated at the end of any of the subdivisions of the whole series corresponding to the records of one stream, it is carried forward into the record of the following stream until the reservoir would have refilled.

The quantities of storage, computed in this way for each year in the 300-year series for each of the six assumed relative rates of draft, are shown graphically on Plate XCVI. This plotting gives a good idea of the periods and of the relative quantities of depletion at the several rates of draft in different parts of the whole series, but it is on too small a scale to be used as a basis of further calculation, and the actual figures from which it was made are used for that purpose.

It is interesting to note that the dry periods on the Sudbury and on the Croton River, when computed in this way, show substantially equal quantities of depletion, but that the Wachusett and Pequannock records, taken together, show a period of depletion fully equal to these, and the Gunpowder and South Platte records, taken together, a depletion only slightly less, thus indicating, as far as these data go, that storages as great relatively as those required at the dry

PLATE XCVI.
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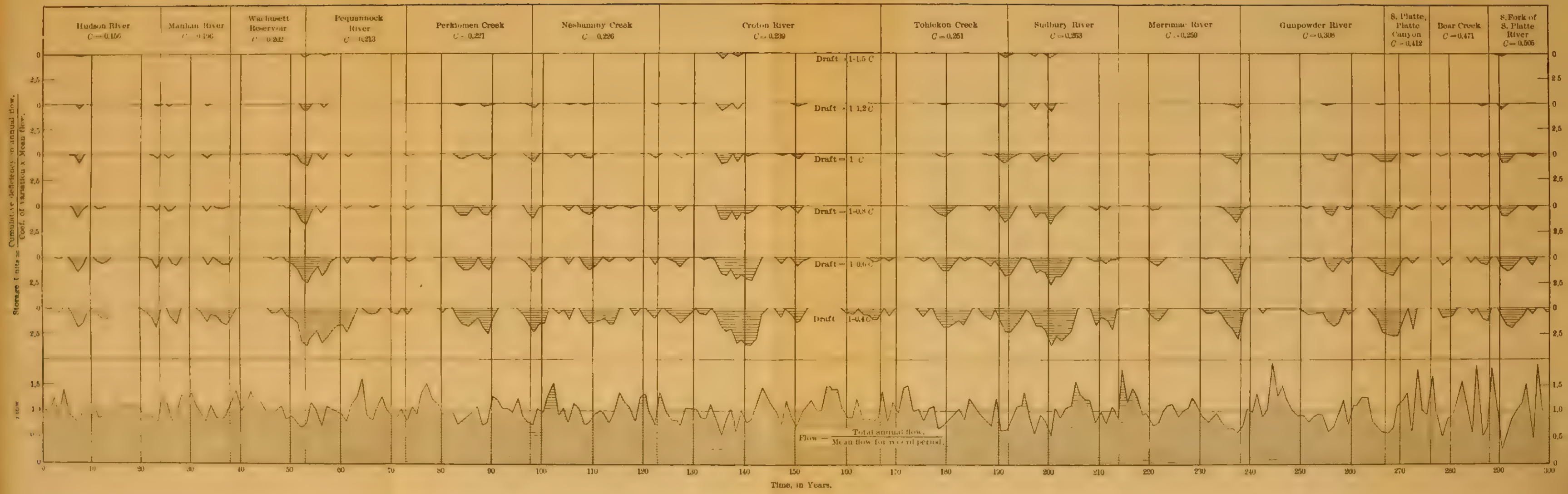
HAZEN ON
STORAGE TO BE PROVIDED
IN IMPOUNDING RESERVOIRS.

DISTRIBUTION OF ANNUAL STORAGE PERIODS.



times about 1880 for the Croton and Sudbury may be expected to recur from time to time in other streams.

The plottings also indicate that the method of bringing the coefficient of variation into the calculation has practically accomplished the desired purpose of arranging all the records so that the computed number of storage units do not differ, or at least do not differ widely, for streams having high coefficients of variation, and for those having low ones. In other words, the depletion for the various relative drafts is about as high at one end of the diagram as at the other. If the adjustments were not fairly well made, there would be an excess of storage indicated at one of the ends.

On Plate XCVII are plotted, for each of the six rates of draft, the figures representing the cumulative number of storage units at the end of each of the 300 years, or as many of them as show depletion, arranged in the order of their magnitude, and lines have been drawn to represent, as nearly as possible, the normals for each series. This plotting is made on probability paper. The lines drawn to represent the data are straight, and the deviations of individual points from them are small. From this diagram the values in Table 13 are taken.

TABLE 13.—ANNUAL STORAGE, IN UNITS OF STANDARD VARIATION IN ANNUAL FLOW, REQUIRED TO BALANCE ANNUAL FLUCTUATIONS IN STREAM FLOW WITH VARIOUS RATES OF DRAFT.

Relative rate of draft.	80% dry year.	90% dry year.	95% dry year.	98% dry year.	99% dry year.
$1 - 0.4C$	1.40	2.01	2.52	3.10	3.48
$1 - 0.6C$	0.75	1.21	1.59	2.02	2.31
$1 - 0.8C$	0.30	0.65	0.95	1.28	1.49
$1 - 1.0C$	0.04	0.31	0.55	0.81	0.97
$1 - 1.2C$	....	0.07	0.27	0.47	0.62
$1 - 1.5C$	....	....	0.00	0.19	0.31

In Table 13A the coefficient of variation of mean annual flow has been determined from certain other streams for which run-off records are available, for the purpose of getting a somewhat broader basis for forming a judgment of the probable coefficient of variation for other streams. No effort has been made to secure completeness in this table, which has only been extended to cover certain data readily available, mostly from records of the U. S. Geological Survey.

Final Arrangement of Annual Storage.—The data of Table 13 have been replotted in Fig. 30, lines being drawn for years of each of

the five degrees of dryness used in the calculation, showing the quantities of annual depletion to be anticipated, plotted on a base of the relative rates of draft. This diagram can be used conveniently in computing the probable annual storage required for a given stream.

TABLE 13A.

Stream.	Catchment area, in square miles.	Years in record period.	Coefficient of variation in annual flow.
Kennebec River, Waterville, Me	4 270	19	0.26
Androscoggin River, Rumford Falls, Me	2 220	17	0.16
Cobbossecontec Pond, Gardiner, Me	240	21	0.25
Mystic Lake, Mass	27	20	0.28
Connecticut River, Hartford, Conn	10 234	13	0.15
Connecticut River, Holyoke, Mass	8 660	19	0.21
Passaic River, Dundee Dam	822	17	0.21
Susquehanna River, Harrisburg, Pa	24 000	20	0.16
Potomac River, Point of Rocks, Md	9 650	15	0.33
Yadkin River, Salisbury, N. C	......	14	0.27
Ocmulgee River, Macon, Ga	2 425	18	0.26
Savannah River, Augusta, Ga	7 294	17	0.25
Ohio River, Wheeling, W. Va	23 800	22	0.16
Tennessee River, Chattanooga, Tenn	22 418	21	0.20
Kansas River, Lawrence, Kans	58 550	14	0.63
Republican River, Junction, Kans	25 837	9	0.61
Arkansas River, Cañon, Colo	3 060	19	0.23
Rio Grande, Del Norte, Colo	1 400	16	0.34
Bear River, Collinston, Utah	6 000	11	0.23
Provo, Provo Cañon, Utah	640	16	0.22
Mill Creek, Salt Lake City, Utah	21	13	0.35
Parley's Creek, Salt Lake City, Utah	50	11	0.58
City Creek, Salt Lake City, Utah	19	10	0.34
Humboldt River, Elko, Nev	2 840	14	0.41
Tuolumne River, La Grange, Colo	1 501	16	0.41
Columbia River, Dalles, Ore	237 000	32	0.20
Willamette River, Albany, Ore	4 860	17	0.26

It may be noted that the expression, "95% dry year", as used herein, does not refer to any particular year. Its use means that, with a given rate of draft and unlimited storage, there would probably be 5 years in 100 when the depletion of storage would exceed the limit shown.

It is probable that 2 or more of the 5 years would follow consecutively in one period of several years of low average flow.

Combined Results for Monthly and Annual Storage.

It is now possible to construct a diagram showing the storage required to maintain various rates of draft for years of different degrees of dryness for a stream for which the mean annual flow, the coefficient of variation in annual flows, and the ground-water storage are known. Fig. 31 shows the Croton data arranged in this way, and

PLATE XCVII.
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NOVEMBER, 1913.
HAZEN ON
STORAGE TO BE PROVIDED
IN IMPOUNDING RESERVOIRS.

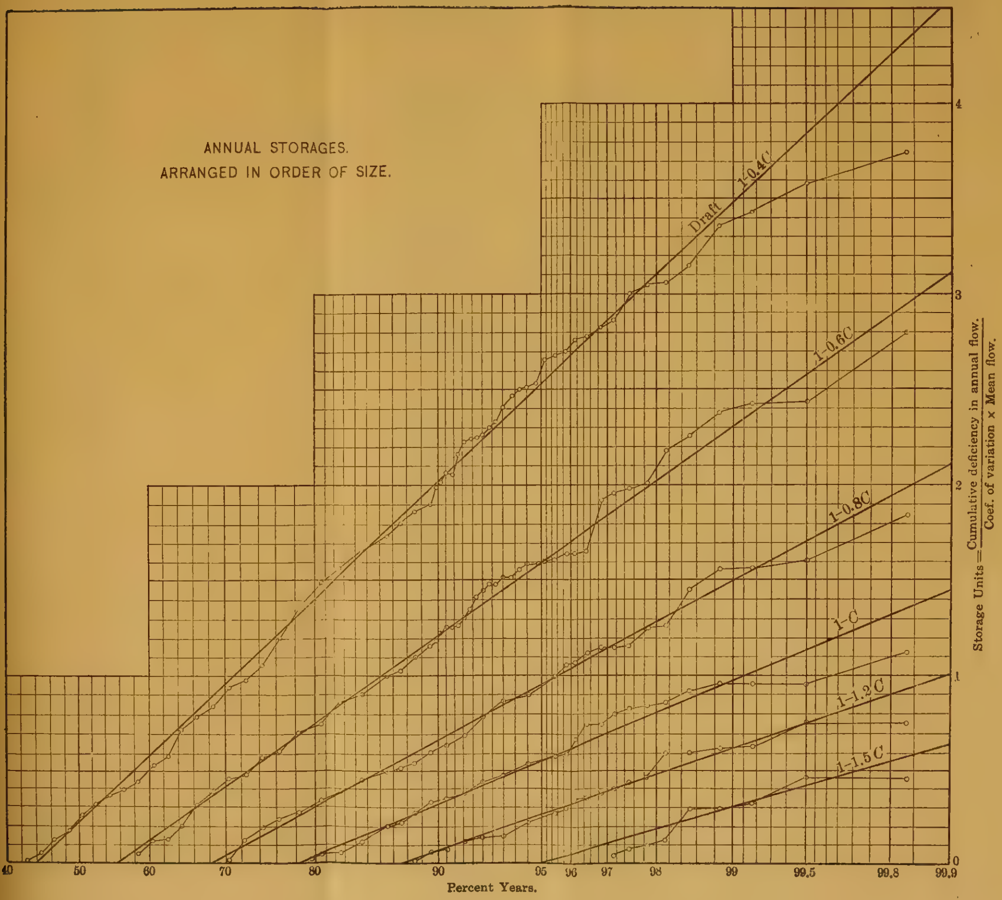


Fig. 32 shows the Sudbury data. Table 14 shows the method by which the figures from which the diagrams are made were obtained.

TABLE 14.—Croton Storage.—95% Year.

Mean annual flow, 1 sq. mile land area, 1 137 000 gal. daily.

Coefficient of variation in mean annual flows, 0.239.

Constant deduction for ground-water storage, etc., Croton River, as in Table 9, 23 days.

Storage unit, 1 137 000 × 365 × 0.239 = 99 500 000 gal.

Draft, in gallons per day per square mile of land area.	Draft divided by mean flow.	Monthly and Daily Storage.			Annual Storage.			
		Days' storage required; normal diagram.	Days' storage less 23 for natural storage.	Storage, in millions of gallons per square mile.	Relative rate of draft.	Units of storage required.	Millions of gallons per square mile of land area.	Total storage required.
1 028 000	0.904	233	210	216	$1 - 0.4C$	2.52	251	467
973 000	0.856	227	204	198	$1 - 0.6C$	1.59	158	356
918 000	0.808	220	197	181	$1 - 0.8C$	0.95	95	276
866 000	0.761	213	190	164	$1 - 1.0C$	0.55	55	219
811 000	0.713	206	183	148	$1 - 1.2C$	0.27	27	175
729 000	0.641	193	170	124	$1 - 1.5C$	0.00	0	124
650 000	0.572	181	158	103	......	......	....	103
600 000	0.528	172	149	89	......	......	....	89
500 000	0.440	154	131	65	......	......	....	65
400 000	0.352	133	110	44	......	......	....	44
300 000	0.264	109	86	26	......	......	....	26
200 000	0.176	80	57	11	......	......	....	11

Using the diagram, Fig. 33, the construction of which will be explained subsequently, the foregoing calculation is more easily made, with the same results, as shown in Table 15.

TABLE 15.

Draft, in millions of gallons per day per square mile of land area.	Draft divided by mean flow.	Days' storage, 95%-year storage diagram.	Days' storage, less 23 for natural storage.	Days' total storage required per square mile of land area.
1.028	0.904	478	455	468
0.973	0.856	385	362	352
0.918	0.808	322	299	274
0.866	0.761	278	255	221
0.811	0.713	240	217	176
0.729	0.641	195	172	125
0.650	0.572	182	159	103
0.600	0.528	173	150	90
0.500	0.440	154	131	66
0.400	0.352	133	110	44
0.300	0.264	109	86	26

On Figs. 31 and 32 two sets of lines have been drawn. The first are solid, and represent figures computed from the normal storage curve with a deduction of the constant found for that stream, which for the Croton is 23 days and for the Sudbury, 25 days. The second set, dotted lines, and the figures from which they are plotted, were scaled from Figs. 8 and 19, with the addition of 9 days for daily storage. In

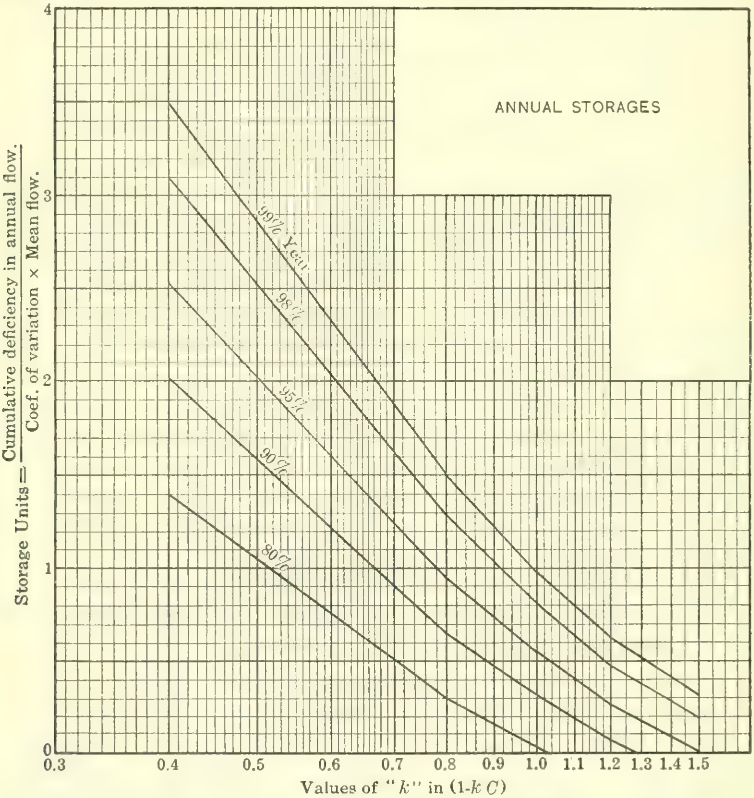
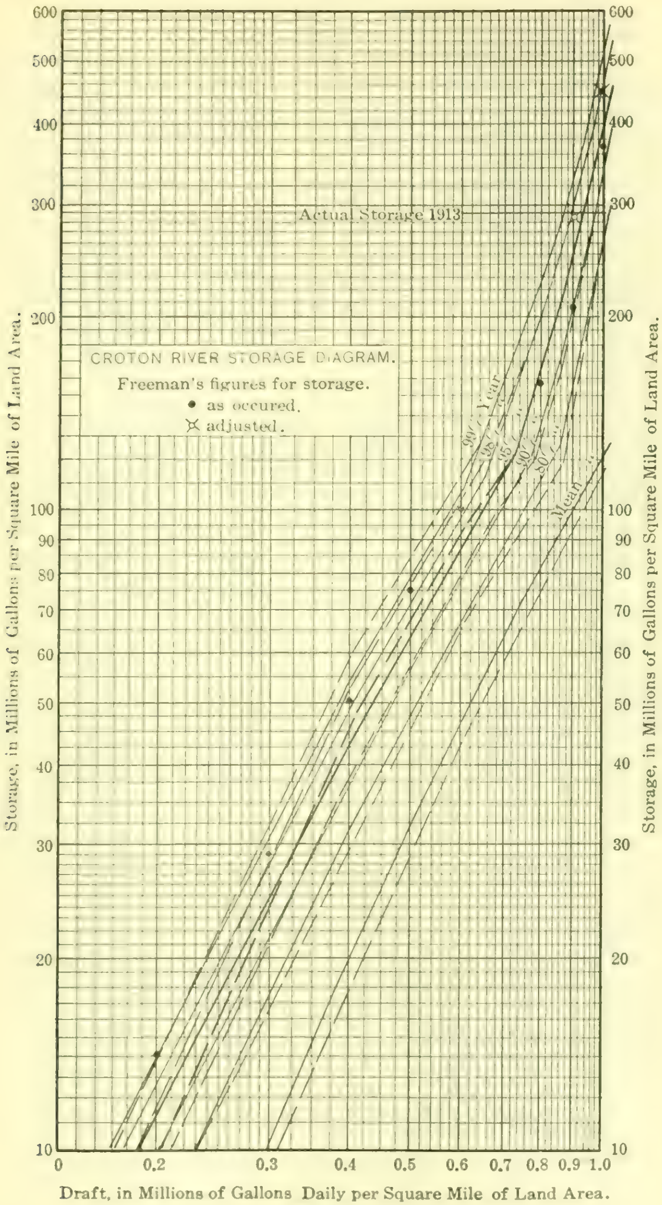


FIG. 30.

other words, they are derived solely from the records of the stream itself, and the normal diagram is not used. The allowances for annual storage were made, in all cases, from the figures in Table 13. Where the two sets of lines were practically in the same position, the dotted one was not drawn. For both the Sudbury and Croton, for the higher rates of draft, which are practically the most important ones, the annual storage



CROTON RIVER STORAGE DIAGRAM.
Freeman's figures for storage.
• as occured.
⌧ adjusted.
Actual Storage 1913
99% Year
95%
85%
90%
80%
Mean
Storage, in Millions of Gallons per Square Mile of Land Area.
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
0
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Draft, in Millions of Gallons Daily per Square Mile of Land Area.

FIG. 31.

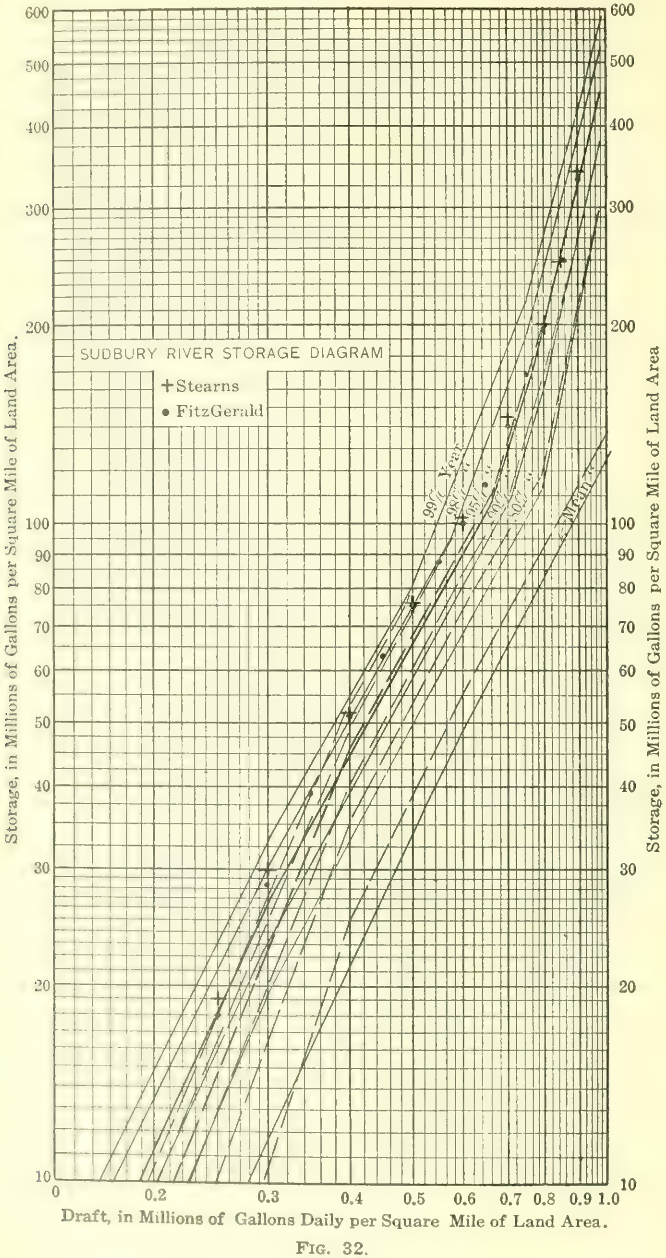

SUDBURY RIVER STORAGE DIAGRAM
+Stearns
• FitzGerald
99% Year
98%
95%
Mean
Storage, in Millions of Gallons per Square Mile of Land Area.
Storage, in Millions of Gallons per Square Mile of Land Area
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
0
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Draft, in Millions of Gallons Daily per Square Mile of Land Area.

FIG. 32.

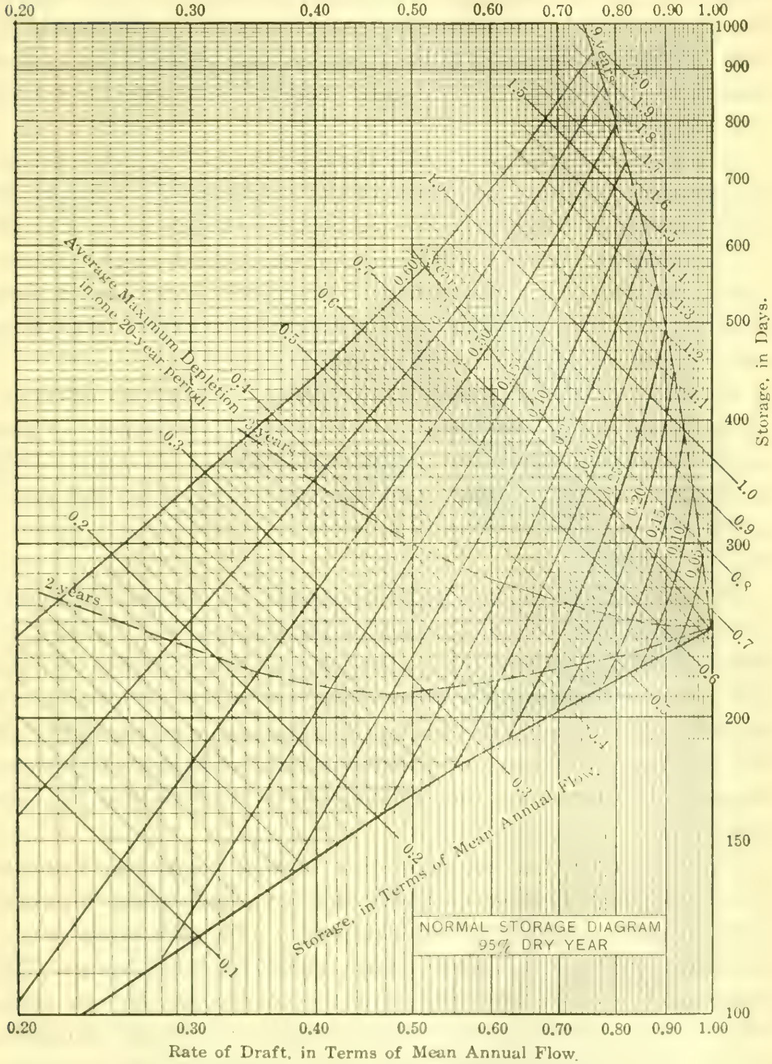

0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
1000
900
800
700
600
500
400
300
200
150
100
Storage, in Days.
Average Maximum Depletion in one 20-year period.
2 years
Storage, in Terms of Mean Annual Flow.
NORMAL STORAGE DIAGRAM
95% DRY YEAR
Rate of Draft, in Terms of Mean Annual Flow.

FIG. 33.

dominates, and it makes no appreciable difference which of the two methods of calculation is used. For the lower rates of draft, there are deviations. In the Croton these deviations are small; in the Sudbury they are greater. In the latter the lines showing the actual records for years of different degrees of dryness are somewhat closer to one another than those deduced from the normal diagram, and with the Croton they are farther apart.

It is a matter of debate whether the lines obtained from the normal storage curve, or from the records of the stream itself, best represent the conditions on a particular stream. On the Croton, with its longer record, it makes but little difference. On the Sudbury, with a shorter record, the divergencies are greater. The writer feels that the lines obtained from the normal storage curve are more reliable than those from this relatively short-record period.

Critical Storage.—The point in the storage curve which marks the beginning of the use of storage to carry water over from one year to another is characterized by a well-marked angle. As many of the phenomena of storage differ somewhat, below and above this point, it will be convenient to give this angle a name, and it will be called the "critical point".

The values for storage found and used by Messrs. FitzGerald, Stearns, and Freeman, and stated in their several publications, are plotted on these diagrams for comparison with those calculated at this time. In a general way, for values below the critical point, they correspond to the 98% dry year; above that point they correspond to the 95% dry year. In other words, they represent conditions which would be expected to recur not oftener than once in 50 years and 20 years, respectively.

There is a particularly interesting case in connection with the Croton, where the storage, as first computed by Mr. Freeman, for drafts of 900 000 and 1 000 000 gal. per day per sq. mile, gave results which, as plotted on Fig. 31, come between the 90 and 95% years. Mr. Freeman showed, by an analysis of the conditions, that an extraordinary rain occurred in the middle of what was otherwise the driest period. He considered that there was no certainty of like rains occurring coincidently with other similarly dry periods, and made certain allowances on the basis that the quantity of rain that actually fell might have been less. He concluded that certain larger values

should be used in estimating storage requirements. His revised data, as plotted in Fig. 31, fall but little below the estimate for a 98% year, except that for a draft of 800 000 gal. per day per sq. mile, which is near the 95% dry year line.

A comparison of the whole curve indicates the desirability of the corrections that Mr. Freeman made, and suggests that they might have been extended with advantage to the computed storage for a draft of 800 000 gal. per day per sq. mile. As this was not done, and as it happens to be near the point for which estimates were most frequently made in Mr. Freeman's work, the single exception is of the greatest importance.

This incident, with a recalculation which added 30% to the storage considered necessary to maintain the higher rates of draft, an addition so large that it overshadows all allowances for evaporation, ground-water storage, and other secondary conditions, shows clearly that even a 30-year period, which was the length of the Croton records at the time this calculation was made by Mr. Freeman, is entirely too short to form an adequate basis for estimating the annual and total storage required. It shows the need of a broader base of data for making such calculations.

Practically speaking, the application of the Croton data and of the Sudbury data, by the methods which have been most commonly used, and for relatively high rates of draft, have corresponded nearly with the 95% dry year by the method of calculation now used.

Some Questions as to Combining the Two Series of Results.—It may be that the driest year, from the standpoint of storage required to balance the daily and monthly fluctuations, will not also be the driest year from the standpoint of the storage required to balance annual fluctuations. In other words, the greatest storage in the two series of calculations may not be strictly cumulative.

An examination of the tables of results shows that the periods driest in one series are always dry periods, if not the driest, in the other, and the storages, therefore, are nearly, if not absolutely, cumulative.

It may be that it would be found (for example, if data were available to make the full comparison) that, in computing the combined storage for the 98% year, the storage required to balance annual fluctuations for 98% of the time should be added to the storage required

to balance monthly fluctuations up to 90% of the time, or to some other proportion than 98 per cent. On the other hand, it must be kept in mind that, in calculating the storage required to balance annual fluctuations, the average flows for the calendar years only have been considered, and, if the data were examined in more detail, periods of 365 consecutive days would be found having lower mean flows than those of any calendar year. So far as this condition exists, there would be a tendency to require somewhat more storage than is computed for the driest years. Conditions of this kind would tend to round off the angle at the critical point in the storage curve.

The results for cumulative storage in Table 1 for the various streams were examined to see how far they would throw light on this, and also the studies of Messrs. FitzGerald, Stearns, and Freeman, previously referred to. The data are not numerous enough to give a clear-cut indication of any tendencies that there may be at this point, and, in the absence of such indications, it may be considered that the two series of storage results are, for practical purposes, cumulative, and that the results obtained by adding one to the other are to be accepted.

Normal Diagram of Stream Flow Combined with Cumulative Storage.—It is now possible to make a diagram, combining the normal flow required to balance the daily and monthly fluctuations shown in Fig. 26 with the cumulative storage required to balance fluctuations in annual flow represented by Plate XCVII and Fig. 30. Such a diagram, for a 95% dry year, is presented in Fig. 33. It shows the storage in days' flow required to balance the daily and monthly fluctuations, being the same as the 95% year line in Fig. 26, to which have been added, for all rates of draft above the respective critical points, the required annual storages for streams having coefficients of variation in annual flows ranging from 0.05 to 0.60.

The point of critical storage for each condition is indicated by the divergence of the line for that particular coefficient from the heavy diagonal base line which represents storage for all streams below their critical points.

As a matter of convenience, diagonal lines have been drawn on this diagram, showing the ratios which the required storage bears to the mean annual flows of the streams. Other lines have been drawn, to correspond with figures to be developed in a subsequent paragraph,

showing the points at which the reservoir will probably be less than full for periods of 2, 3, 5, and 9 years, respectively, in an average 20-year period.

Fig. 34 was prepared in the same way, but represents a 98% dry year. Similar diagrams could be prepared for 90 and 99% years, if it were desired.

The correction for natural storage and other peculiarities of the catchment area, shown for the streams for which data are available in Table 9, must be deducted from the quantities of storage taken from these diagrams.

Figs. 33 and 34 afford the most convenient means of estimating the size of reservoir required to maintain a given rate of draft, and, on the other hand, of estimating the probable draft that can be maintained from a given catchment area and storage reservoir.

Application to Data for Several Streams.

In Fig. 35 the foregoing data, arranged for a 95% year, have been applied to the records of the eastern streams used in this discussion, and the results have been reduced to gallons per square mile of land area of flow and storage in each case. This diagram shows, in compact form, how the storages required on different streams differ from each other; it will be found convenient for making estimates of stream flow when the record of a particular stream is to be used as a basis.

The lines have been continued at the upper end to the point where, as will be shown in a subsequent section, the reservoir will probably remain less than full for 9 years in an average 20-year period.

Rainfall.—The relation between rainfall and run-off is one that has been much discussed, and one that is not to be taken up in this paper. It may be mentioned, however, that studies of rainfall records indicate that the methods of analysis herein proposed for run-off data are also applicable to rainfall records.* The standard variation in rainfall is not very different from the standard variation in run-off for the same area in some cases, as shown by Table 16.

* Sir Alexander R. Binnie's well-known work on rainfall, in Vol. XXXIX, *Minutes of Proceedings*, Inst. C. E., suggests this, although the data were not arranged in the way now proposed. The late George W. Rafter, M. Am. Soc. C. E., suggested the application of the method of least squares to rainfall data in the report of the New York State Engineer for 1896, with a view to deducing the probability of occurrence of certain conditions of low flow, and announced the intention to discuss in some future report the final theoretical question of methods of deducing a formula to enable one to take the rainfall and temperature records of a long series of years and deduce therefrom the probable yearly run-off of a stream.

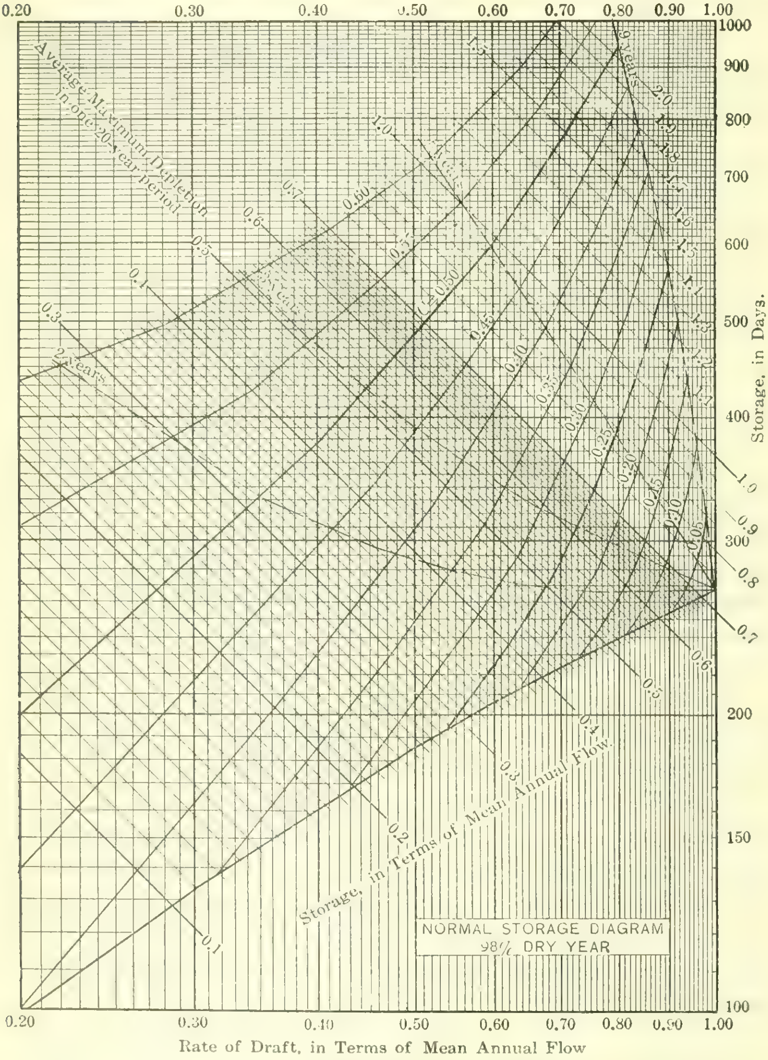

0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
1000
900
800
700
600
500
400
300
200
150
100
Storage, in Days.
Average Maximum Depletion in one 20-year period
Storage, in Terms of Mean Annual Flow.
NORMAL STORAGE DIAGRAM
98% DRY YEAR
Rate of Draft, in Terms of Mean Annual Flow

FIG. 34.

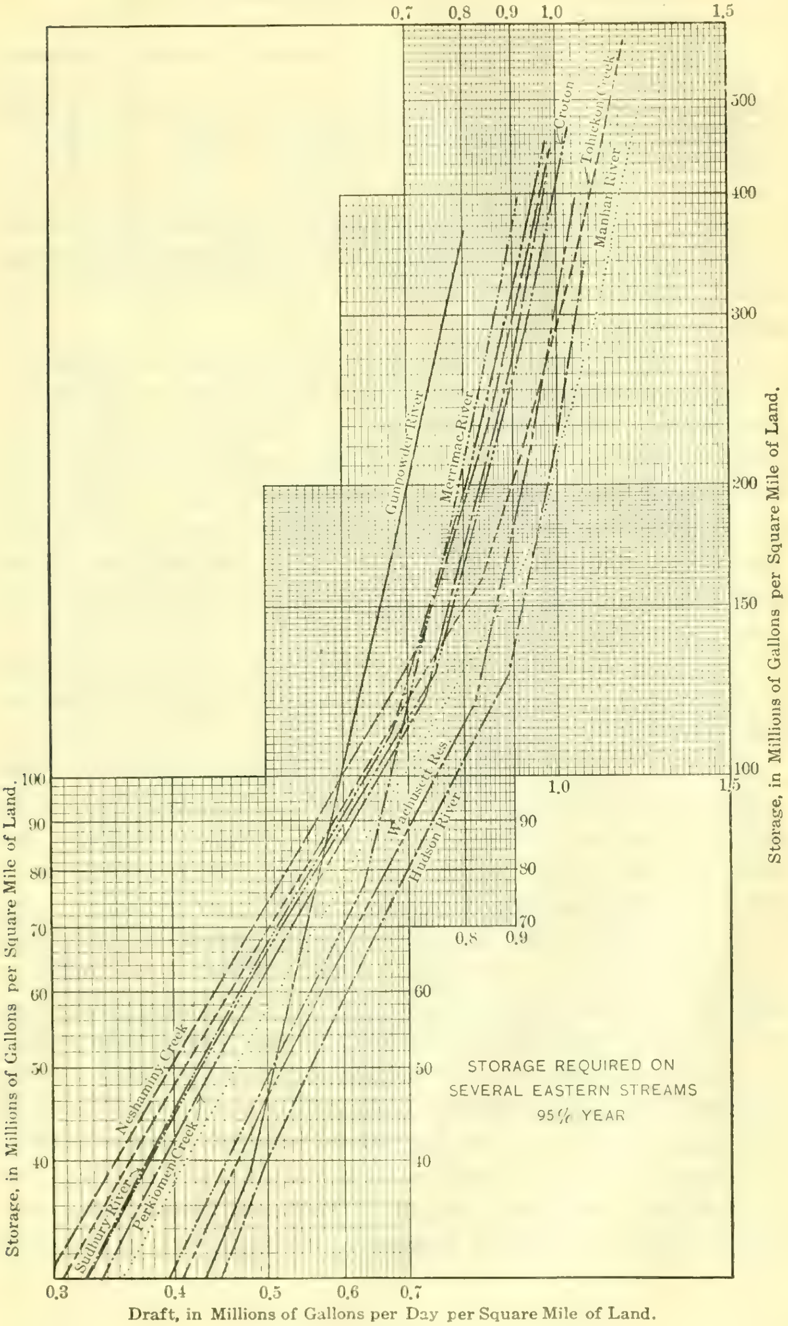

0.7
0.8
0.9
1.0
1.5
500
400
300
200
150
100
Croton
Tohickon Creek
Manhan River
Gunpowder River
Merrimac River
Wachusett Res.
Hudson River
Neshaminy Creek
Perkiomen Creek
Sudbury River
100
90
80
70
60
50
40
0.8
0.9
1.0
1.5
0.3
0.4
0.5
0.6
0.7
Storage, in Millions of Gallons per Square Mile of Land.
Draft, in Millions of Gallons per Day per Square Mile of Land.
STORAGE REQUIRED ON
SEVERAL EASTERN STREAMS
95% YEAR

FIG. 35.

TABLE 16.—RAINFALL AND RUN-OFF COMPARED.

	Croton.	Sudbury.	Wachusett.
Mean annual rainfall	48.8 Inches	45.5 Inches	46.5 Inches
Mean annual run-off	24.0 "	22.9 "	24.0 "
Standard variation in annual rainfall	6.0 "	6.5 "	6.6 "
Standard variation in annual run-off	5.7 "	5.7 "	4.8 "

The agreement between these figures is interesting, and suggests a means of forming an idea of the probable standard variation in mean annual run-off from rainfall records in cases where adequate stream gaugings are not available.

As to the Shortage in Years Drier Than the Limit Adopted.—If storage is provided to maintain the flow 19 years out of 20, the question must be considered as to how much the available supply will fall below the nominal supply in the twentieth year. The twentieth years will not be alike in their degrees of dryness, and the shortage of water will range from nothing to the quantity indicated as available for the same quantity of storage in the 99% year, and to still lower quantities in years that recur at longer intervals than 100 years.

The water available in the 98% year will be very nearly equal to the average quantity obtainable in all the years drier than the 95% year.

The data for eastern streams indicate that the supply in a 98% year will be less than in a 95% year by from 3 to 9 per cent. The percentage shortage is greatest with small storages and drafts, and least with the highest storages and drafts. As a representative, although not necessarily an average figure, 6% may be taken.

There will be 5 years in a century with deficiency in supply when a 95% year is taken as a basis. Actual records do not suffice to show the shortages in these years. Records many times longer than those available would be required for this. Not having such records, it seems probable that the normal law of error will apply at least approximately, and that probability paper may be used for a graphical solution of this problem. In Fig. 36 the basis of such a calculation is indicated. A line is drawn passing through 100% in the 95% year, and 94% in the 98% year, and this is continued. Values taken from it indicate that the probable shortage in the 5 dry years of a century

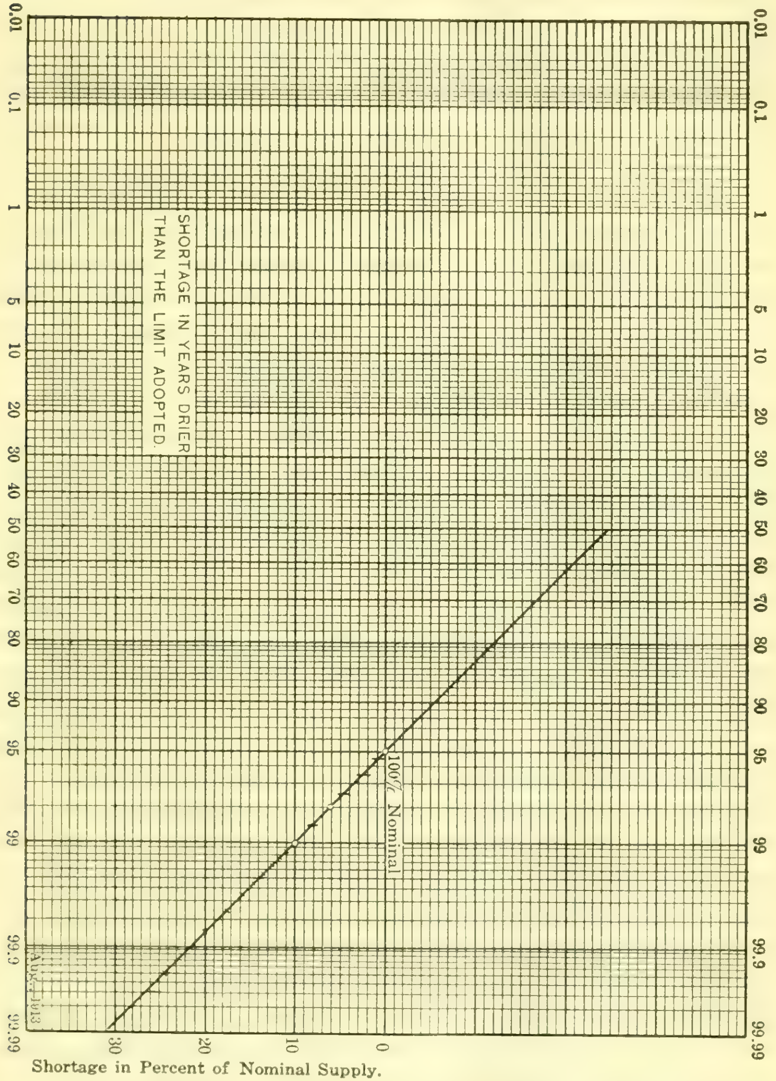

SHORTAGE IN YEARS DRIER THAN THE LIMIT ADOPTED.
100% Nominal
0.01
0.1
1
5
10
20
30
40
50
60
70
80
90
95
99
99.9
99.99
30
20
10
0
Shortage in Percent of Nominal Supply.

Fig. 36.

will be 1, 3, 5, 8, and 14%, respectively, averaging 6 per cent. If the 98% year is taken as a basis, there will be 2 years in a century when the supply will be short, and the shortage in these years will probably be 2 and 8%, respectively, averaging 5 per cent. If the 99% year were used as a basis, there would be 10 years in 1 000 with less than full supply, and the probable shortage for them, computed in a similar way, would be ½, 1, 2, 2, 3, 5, 6, 8, 10, and 15%, respectively, averaging 5 per cent.

These figures are to be taken as representing the probabilities of certain shortages of water. It is to be expected that the years of shortage, with high rates of draft and storage, would be in groups such as occurred in the Croton and Sudbury Rivers. By the methods of calculation used, the rate of draft that could be maintained by a given storage through such a group of dry years would be taken as applying to each of the dry years in that group. As a result, it would be found that the years of shortage, instead of forming a regular series, as in the figures just given for illustration, would occur in a certain number of groups, for each of which there would be a single rate of shortage. This is another illustration of the fact that much more numerous data must be had before the full series indicated by the normal law of error can be filled out. The figures obtained by such estimates must be regarded as the most probable ones on the basis taken, from which there are certain to be deviations.

As a result of the foregoing study, it appears that using the 98% dry year as a basis does not mean that the shortage in the dry year, when it finally arrives, will be materially less relatively with reference to the standard than would be the case with the 95% year or the 90% year used as a basis, but it does mean that the probability of the occurrence of such a year in any period is smaller.

The Effect of Error in Mean Annual Run-Off.—The mean annual run-off is known only approximately, the accuracy being greater as the records on which it is based are longer. It may be important to know how much reduction in available capacity would be suffered in case the mean proved to be less than the quantity used as the basis of the calculation.

With a fixed quantity of storage, the reduction in available draft is not in proportion to the reduction in run-off; the percentage that

is utilized becomes greater as the run-off is smaller. Below the critical storage, with a fixed quantity of storage, 2% reduction in mean annual run-off results in about 1% reduction in the net available supply. Above the critical storage, 5% reduction in the mean annual run-off reduces the net available supply by about 4 per cent. These figures will vary somewhat with different assumed conditions, but they are sufficiently close for use in considering the probable effect of errors in the mean flows that are used.

As to the Accuracy of Averages of Short-Term Records.

A study was made to see whether the probable variations of short-term averages followed the rules given in the textbooks, and if not, to see how they vary from them.

The probable error of the average in a series of random data is:

$$\frac{\text{Probable error in one term}}{\sqrt{\text{Number of terms}}}.$$

It is proposed to see whether the figures representing mean annual flows of a stream for a term of years vary as if each number were drawn out of a bag containing numbers representing all the terms of the series, or whether they occur in cycles in such a way as to modify short-term averages.

To test this point, the relative mean annual flows of the Croton River and Neshaminy, Tohickon and Perkiomen Creeks, were selected. Each has a record of 25 years or more, and the coefficients of variation are near together. All shorter-term records are excluded, and also the Gunpowder River, because of its higher coefficient of variation. The coefficient of variation of the whole series of 120 years is 0.235.

The figures were first divided into sixty series of 2 years each. The sixty average results form a new series, and the probable error of one term in it is ascertained. The same process was followed for other lengths of period.

The probable errors thus found were compared with those computed by the formula just given.

As a check on the work, the number representing each term in the 120-year series was written on a piece of paper, these pieces of paper were mixed and drawn and written down as drawn, forming a new series in which the terms are identical with the terms in the

first series, but in which any tendency to cycles is presumably destroyed. This series was then divided, and the probable errors of short-term averages were determined as had been done in the first place.

The probable errors computed and found in the seven series are given in Table 17.

TABLE 17.

Number of series.	Number of terms in each series.	PROBABLE ERROR IN AVERAGE OF EACH SERIES.		
		As computed from formula.	Series I, as occurred.	Series II, with the numbers as drawn.
120	1	15.9	15.9	15.9
60	2	11.2	12.4	11.1
40	3	9.2	10.0	9.7
30	4	7.9	10.3	8.5
24	5	7.1	8.0	5.6
20	6	6.5	8.9	5.0
15	8	5.6	7.6	5.0
12	10	5.0	5.7	4.8
10	12	4.6	4.3	4.3
6	20	3.5	5.7	4.3
4	30	2.9	3.0	2.8
3	40	2.5	1.9	2.0

The averages of periods of from 4 to 8 years have probable errors averaging 2% greater than those computed by the formula. In shorter and longer terms the excess is not more than 1 per cent. The same figures as drawn to destroy cycles, if such existed, yielded results differing from the calculated results as often in one direction as in the other. The method of calculation is thus supported, and may be accepted, except so far as it is modified by the existence of cycles in the records. The figures indicate the presence of cycles, and an appreciably, although not large, influence from them in the average accuracy of short-term averages.

Taking this influence into account, to get an average result for which the probable error will not exceed 10% with streams like those used as a basis for this study, a 4-year record is necessary. To reduce the probable error to 5%, a 12-year record is necessary, and to reduce it to 3%, 2%, and 1%, records of 28, 63, and 250 years, respectively, are required.

The probable errors of the means for the eastern streams, for the records used in this study, range from 2.1% for the Hudson to 3.8%

for the Gunpowder. In general, a 3% probable error for these data may be assumed.

By the normal law of error, the average error is 18% greater than the probable error. Using the "probable error" as the standard of comparison, or the measure of magnitude of actual errors, and considering the law of normal error, the following relations may be stated: There is one chance in 2 that the actual error in the mean flow will exceed the probable error; that is, the actual error is as likely to be on one side of the probable error as on the other. There is one chance in 4 that the true mean of a series will be less than the record mean of that series by a quantity greater than the probable error. There is one chance in 11 that it will be less than the record mean by more than twice the probable error; one chance in 46 that it will be less than the record mean by more than three times the probable error; and one chance in 286 that it will be less than the record mean by more than four times the probable error. The chance that the true mean of a series will lie above (be greater than) the record mean by a given quantity is the same as the chance that it will lie below (be less than) by that same quantity, but the chance is twice as great that it will lie either above or below by the given quantity.

Probable Error in the Coefficient of Variation.—The probable error in the coefficient of variation, as determined by short-term records, is also a matter of importance, as the coefficient of variation plays a part only second to that of the mean flow in estimating the storage required for the larger drafts with the methods now proposed.

In computing the coefficient of variation from short-term records, it is better to divide the sum of the squares of the variations by $n - 1$ instead of by n. Otherwise, the values for the coefficient decrease with the shortness of the period. With longer records, the difference is not important. In records as short as from 5 to 10 years, the difference is essential.

The average coefficient of variation for the twenty-four 5-year periods previously described was found to be 0.219 as occurred, and 0.228 with the numbers drawn. These may be compared with 0.235, found for the whole series. The probable error of one 5-year determination was found to be 19.8% as occurred and 23.5% as drawn.

In other words, the probable error in the coefficient of variation deduced from one 5-year term is about 20%, and occasionally the variation will greatly exceed this.

The average coefficients of variation for the twelve 10-year periods were found to be 0.225 for the figures as occurred, and 0.230 for the figures as drawn, and the probable errors in the coefficient deduced from one 10-year series were 12.2 as occurred and 16.0 as drawn.

The tendency of the figures as occurred to run in cycles may be the reason for the lower variation in such figures as compared with the figures as drawn.

The probable error in the coefficient of variation for other periods may be assumed to vary inversely approximately as the square root of the length of the period. The figures for the periods as they occurred are preferred to those for periods as drawn, and on this basis a 17-year record is necessary to obtain a figure with a probable error of 10%, and a 69-year record to determine the coefficient of variation with a probable error of 5 per cent.

The errors in the coefficient of variation in the data deduced for the several streams discussed at this time are thus probably within from 7 to 12% of the truth.

It is clear that short-term records must be used with caution in determining the coefficient of variation, and longer records of other streams, more or less similar to the one under discussion, may often give a better indication of the probable value of this coefficient than short-term records of the stream itself.

An error in the coefficient of variation of the mean annual flow of a stream does not affect the required storage below the critical point. Above this point the effect can be best seen in Fig 33. For example, it appears that, with a given storage, about 5% more water is available when the coefficient of variation is 0.20 than when it is 0.25, all other conditions being equal.

Tabular Statement of Data and of the Probable Errors Therein.—For convenience, the principal data with reference to the several streams are brought together in Table 18. The probable error in the mean flow and the probable error in the coefficient of variation, computed by the methods previously indicated, are shown as percentages of the total. The probable error in the deduction in days' storage, be-

cause of natural storage, is given in days, and is found by the formula:

$$x = \frac{0.674 \text{ standard variation in days}}{\sqrt{\text{number of years in record}}}.$$

The standard variation is taken as the value when about half of the mean flow is utilized.

TABLE 18.—SUMMARY OF DATA.

Stream.	Number of years in record.	Mean annual flow, in millions of gallons per square mile daily.	Coefficient of variation in mean annual flow.	Days to be deducted from normal storage diagram.
Bear Creek	11	0.188 ± 9.5%	0.471 ± 12.5%	64 ± 5
Catskill	17	1.400	....	5 ± 6
Croton	45	1.137 ± 2.4%	0.239 ± 6.2%	23 ± 5
Gunpowder	29	0.911 ± 3.8%	0.308 ± 7.7%	91 ± 5
Hudson*	24	1.135 ± 2.1%	0.156 ± 8.5%	73 ± 4
Manhan	14	1.317 ± 3.5%	0.196 ± 11.1%	25 ± 8
Merrimac*	24	1.020 ± 3.6%	0.259 ± 8.5%	66 ± 4
Neshaminy	25	1.083 ± 3.0%	0.226 ± 8.3%	10 ± 6
Pequannock	20	1.423 ± 3.2%	0.213 ± 9.3%	....
Perkiomen	25	1.080 ± 3.0%	0.221 ± 8.3%	33 ± 5
South Fork	11	0.053 ± 10.2%	0.505 ± 12.5%	*add* 20 ± 11
South Platte	8	0.075 ± 9.8%	0.412 ± 14.7%	40 ± 8
Sudbury	22	1.085 ± 3.6%	0.253 ± 8.8%	25 ± 5
Tohickon	25	1.310 ± 3.4%	0.251 ± 8.3%	2 ± 6
Wachusett	15	1.136 ± 3.5%	0.202 ± 10.7%	61 ± 5

* No allowance made for water area.

Probable Error in Computed Quantity of Supply, from Short-Term Records.—The errors resulting from errors in mean flow and from errors in coefficient of variation are not cumulative, because these phenomena are closely related, and the existence of a tendency to short-term cycles is an element in the results.

To determine the probable error in results obtained from short-term averages, the figures for each of the 5-year terms and the 10-year terms in the above mentioned series, were used as a basis for estimating the maintainable yield, with a storage equal to 60% of the mean annual flow for the whole term. The relative results would obviously depend somewhat on the quantity of storage assumed. Only one storage figure was used, however, this being selected to represent a reasonably complete development.

In making these estimates, allowances for ground-water and evaporation were omitted, as they would be nearly the same for each series, and in comparative results they are not important. The yield from this storage, computed from the uniformity coefficient for the whole series, is 78% of the mean flow. For twenty-four 5-year periods, each

considered by itself, the average computed run-off was 78%, with a probable error of 6.4 per cent. One 5-year period (Croton, 1898-1902) indicated a maintainable yield 22% above the average, and the difference was more than three times the probable error. If this were used as a basis for estimating the yield of the Croton River, the actual yield would be less than calculated by 18 per cent.

The twelve 10-year series give a general average of 78.3% and a probable error for one series of 5.1 per cent. One term (Croton, 1898-1907) indicated a maintainable yield 13% above the mean, the difference being two and one-half times the probable error. The probable errors are shown in Table 19.

TABLE 19.

	In one 5-year term.	In one 10-year term.
Probable error in mean flow	8.0%	5.7%
Probable error in coefficient of variation	19.8%	12.2%
Probable error in available yield, with fixed storage, remaining the same in each series, and equal to 0.6 of the mean flow for the whole term	6.4%	5.1%

As a summary of the entire study, it may be said that the probable error in the calculated maintainable yield of an eastern stream, above the critical point, for conditions like those on the streams investigated, would be a little less than the probable error of the mean flow, and, for 10-year records and greater, may be represented approximately by the formula:

$$\text{Probable error} = \frac{0.55 \times \text{coefficient of variation}}{\sqrt{\text{number of years in record}}}.$$

It must be remembered there is one chance in 4 that the true result will be less than the quantity computed in a short-term record by more than the probable error; one chance in 11 that it will be less by more than twice the probable error, and one chance in 46 that it will be less by more than three times the probable error. The Croton records for 1898-1902 may be cited as indicating a deviation from the 45-year mean equal to more than three times the probable error for one 5-year period. Such errors may practically be guarded against in many cases by the fact that a short-term record giving such an unusually high mean, as compared with the true mean, would be certain to be a period in which the rainfall and run-off were so much above the normal that the excess would have attracted attention.

The variations in flow of different areas are such that errors up to the probable error and somewhat above it might easily escape detection in this way; but, with errors two or three times as great as the probable error in one short-term series, the cases would be rare when some local evidence of unusual conditions could not be obtained by careful inquiry that would serve as a warning against placing too much dependence on the short-term average.

Cycles in Run-Off.

On Plate XCVIII are shown the relative annual yields of the several eastern streams for each year, and also the required quantities of monthly storage to maintain drafts of 400 000, 600 000, and 800 000 gal. per sq. mile of land area from each stream.

This diagram shows that periods of wet weather and dry weather extended generally over the area occupied by these streams, so that in a general way, the fluctuations are somewhat similar.

Wide local differences are shown, and these are much wider in some years than in others. Generally, the fluctuations above the mean are greater in magnitude and shorter in duration than those below the mean. One year, 1889, was notably wetter than any other covered by the records.

Only the Sudbury and Croton records go back to the dry period in the early Eighties, and they do not indicate the recurrence of other years as dry. However, there are some years, notably 1895 and 1900, and 1908, 1909, and 1910, when the required monthly storage on some of the streams was as great, or nearly as great, for some of the drafts, as was the case in 1880 and in 1884 for the Sudbury and Croton.

The general impression obtained from inspection of the diagram is that there are cycles, and that a median line of annual yields will be found to have a high point in 1878, swinging down to a low point in 1882, a summit in 1889, a low point in 1895, a summit in 1903 and another low point in 1910, indicating, in a general way, cycles with periods of from 10 to 12 years, but with some minor summits and low points, which, if taken into account, would shorten the average period.

Long-Term Cycles in Run-Off.—There is no direct experimental evidence sufficient to serve as a basis in investigating the existence and magnitude of long-time cycles. There are some indirect data, especially from rainfall records. The relation between rainfall and

run-off is not exact, but the demonstration of cycles in rainfall records may be taken as evidence of the existence of like cycles in run-off records, although the percentage variation would not be expected to be the same.

Vermeule* gives a summary of long-term rainfall data in the United States, and states:

"A careful study of these long series shows a strong tendency to cycles of high and low precipitation. We are likely to have a period of years of high average rainfall, followed by a low period. We see at once that, under these conditions, differences shown by comparing a series of eight or ten years' length at one station with a fifty or sixty-year series at another, may be entirely differences of time and not of place."

A chart at the same place shows the secular changes in annual rainfall. In the Philadelphia record, in 68 years there are eight well-defined summits, indicating a complete cycle every 8 years. The summits are not of the same magnitude, but indicate a gradual progressive increase up to about 1868, followed by a subsequent decrease.

Arthur T. Safford,† M. Am. Soc. C. E., states:

"It is interesting to note that the average precipitation by 10 year periods rose steadily from 1832 to between 1880 and 1890; since which time the average has begun to decrease. While we should not attach too much significance to this, the fact remains that if we ever have 10 continuous years with as low an average precipitation as fell during the years previous to 1840, a good many water supplies in the state will have to be enlarged.

"These differences in rainfall are so clearly marked that I will show this comparison in the form of the following table and diagram:‡"

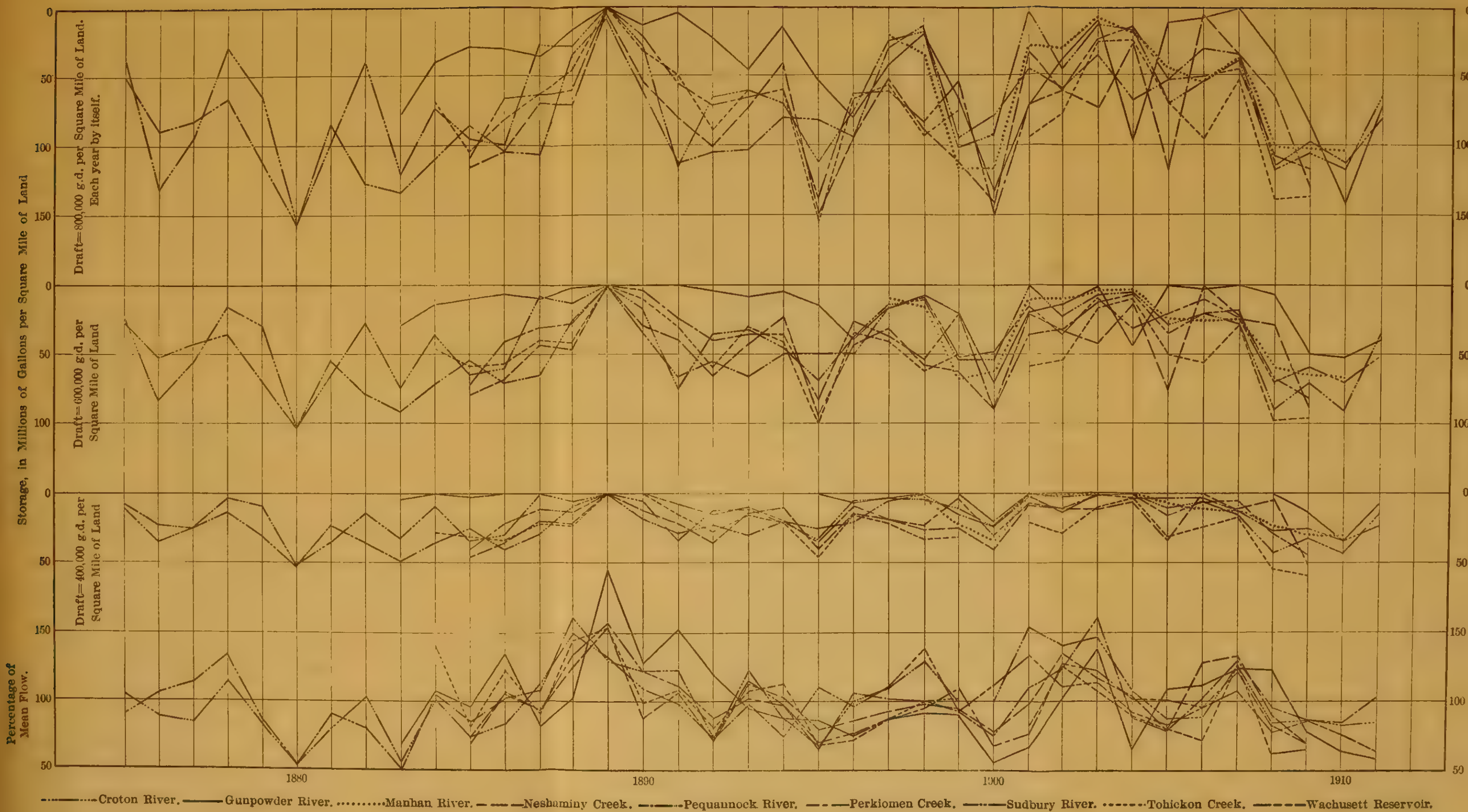
" Period Average of	LOWELL.	PROVIDENCE.	NEW BEDFORD.	BOSTON.	AVERAGE OF 4 STATIONS.
	Inches.	Inches.	Inches.	Inches.	Inches.
9 Years, 1832–1840.....	37.98	36.87	44.27	41.02	40.03
10 " 1841 1850.....	40.27	41.21	44.94	42.88	42.32
10 " 1851–1860.....	44.14	43.73	44.76	50.09	45.68
10 " 1861–1870.....	45.93	47.56	46.27	57.24	49.25
10 " 1871–1880.....	45.24	47.84	46.88	50.26	47.55
10 " 1881–1890.....	46.47	49.07	48.69	48.48	48.18
10 " 1891–1900.....	44.46	48.89	47.72	45.46	46.63 "

* Geological Survey of New Jersey, Vol. III, 1894, p. 12.

† Report on Fall River Water Supply, July, 1902.

‡ The diagram is not reproduced.

DIAGRAM ILLUSTRATING CYCLES IN FLOW AND STORAGE DATA.



Turneaure and Russell* state:

"The question of a gradual change in the yearly rainfall is one the solution of which would doubtless require data covering several centuries. The rainfall for a particular locality may average considerably below the mean for many years, after which may follow, perhaps, an equally long period of surplus. In an analysis of several records extending over many years it was found that during an 83-year period at New Bedford, Massachusetts, the averages for 10-year periods were as high as 16 per cent. above the mean and 11 per cent. below; for 60-year periods the extremes were, at St. Louis, 17 per cent. and 13 per cent., and at Cincinnati, 20 per cent. and 17 per cent. For a 25-year period the extreme variations were 10 per cent. for both New Bedford and St. Louis.† From this it is seen that to establish a reliable mean it requires a record extending over a long period of time.

"The variations or cycles above referred to, that extend over several years, are in some cases very marked, but they are very erratic and as yet quite incapable of being predicted."

They also present a diagram in which the fluctuations of averages of precipitation records of certain localities are given. In the curve representing New England there are six clearly marked summits in the period of 60 years, or one every 10 years.

The line showing Ohio Valley stations has eight summits in a period of 60 years, or an average of one every 8 years, and the fluctuations do not correspond in point of time with those of New England. The progressive change in the general average also does not correspond. The total variation is less than in New England where there was a first summit about 4% above the average in 1848. The line then falls to about 4% below the average in 1872, and a second summit 2% above the average was reached in 1885.

A line for the middle Mississippi Valley shows five summits in a period of 35 years, or, on an average, one every 7 years.

Taking all these data together, there is indication of the existence of cycles with average periods of from 7 to 10 years, and with an ordinary variation in rainfall from 10 or 12% above to 8 or 10% below the mean, in the general swing of the curve, and without going to the extremes of 1 or 2 years. There is also indication of a much longer cycle with a range of not more than 4 to 6% above and below the average, and with a period of 40 to 60 years.

* "Public Water Supplies", p. 41.

† "Bulletin D".

Undoubtedly, there may be other longer cycles, with periods running into centuries, but no data are at hand that could be expected to show them if they exist.

As to the Length of Time that a Reservoir will Remain Less than Full.

There is well-grounded objection to the use of a development so large that the reservoir will be less than full through a considerable period of years. When a reservoir remains drawn down for a long time, vegetation grows on its shores, and much additional work must be done, as it refills, to prevent impairment of the quality of the water by the subsequent decay of the submerged vegetation. This may be less important in the future than it has been in the past, owing to the increasing use of methods of treating and purifying water which will result in the removal from it of deleterious substances resulting from such growths and decompositions. However, the matter remains one of considerable importance, and should not be lost sight of in any study for a complete development.

Methods.—The data from which Plate XCVI was prepared were used and the number of years that the annual flow is less than the corresponding draft and the number of winters during which the reservoir will not refill were counted and the percentages obtained.

From the data referred to above we find for a draft of $1 - 0.4C$, 27 periods in a total of 252 years, varying in length from 3 to 15 years, during which the reservoir is less than full. These are entered in Column 2 of Table 20 in the order of their occurrence and in Column 3 in their order of magnitude.

If the maximum period of depletion is to be computed for a 100-year period, then the 252 years in the whole series will form 2.52 such periods; and the first two terms in Column 3 and 0.52 of the third term are added to make the sum of 32.7 years for depletion for 2.52 such 100-year series. For one 100-year series the average maximum period of depletion is found by division to be $\frac{32.7}{2.52} = 13$ years. In a similar way, there are 8.4 terms of 30 years each, and the sum of eight first terms and 0.4 of the ninth term is 87.2, and the average maximum term of depletion in each 30-year series, 10.4 years. Similar calculations are made for 20 years and for 10 years.

TABLE 20.

Number of term. (1)	Length of depletion period, in years: $d_1\ d_2\ \ldots$ (2)	Figures in Column 1 in order of magnitude: $d_1\ d_2\ \ldots$ (3)	Average maximum period of depletion: D. (4)	Years in period for which D is to be found: P. (5)	$\frac{n}{P}$ = number of terms in summation in Column 2. (6)
1	3	15			
2	8	12	32.7 ÷ 2.52 = 13.0	100	2.52
3	3	11			
4	15	10			
5	4	10			
6	5	9			
7	9	9			
8	6	8	87.2 ÷ 8.4 = 10.4	30	8.4
9	4	8			
10	8	7			
11	3	7			
12	9	6	115.6 ÷ 12.6 = 9.2	20	12.6
13	11	6			
14	4	6			
15	3	5			
16	5	5			
17	7	4			
18	3	4			
19	6	4			
20	10	4			
21	7	3			
22	12	3			
23	3	3			
24	10	3			
25	4	3	165.6 ÷ 25.2 = 6.6	10	25.2
26	3	3			
27	6	3			

Similar tables were made for all the other rates of draft represented in Plate XCVI, and the values obtained plotted, from which smooth curves were drawn, and from these curves values of the average maximum periods of depletion were found, as shown in Table 21.

TABLE 21.—DEPLETION.

Relative rate of draft.	Percentage of years that annual flow is less than the corresponding rate of draft.	Percentage of winters when the reservoir will not refill.	Average maximum period of depletion in one 20-year period.
$1 - 0.4C$	39	58	9 Years.
$1 - 0.6C$	32	43	7 "
$1 - 0.8C$	24	30	5 "
$1 - 1.0C$	17	21	3.5 "
$1 - 1.2C$	10	12	2.2 "
$1 - 1.5C$	3	3	1.5 "

In a 10-year period, the probable maximum period of depletion is about 30% shorter than in a 20-year period; and in a 100-year period, 50% longer.

In using Table 21 it must be borne in mind that periods of depletion as long as those stated will not occur in every 20-year period. The figure given is rather the average length of the longest term of depletion to be expected in each of a considerable number of 20-year periods.

TABLE 22.—RATES OF DRAFT FOR SEVERAL STREAMS WITH THE STATED AVERAGE MAXIMUM PERIOD OF DEPLETION IN EACH 20-YEAR PERIOD.

Stream.	Percentage of water area.	Mean annual flow, in millions of gallons per square mile of land area	Coefficient of variation.	Years of Continuous Depletion on an Average in Each 20-Year Period.			
				9 years $(1-0.4C)$.	5 years $(1-0.8C)$.	3 years $(1-1.1C)$.	2 years $(1-1.3C)$.
Hudson	....	1.135*	0.156	1.064	0.993	0.940	0.905
Manhan	0	1.317	0.196	1.214	1.111	1.035	0.983
Wachusett	4.16	1.136	0.202	1.044	0.952	0.883	0.836
Pequannock	4.15	1.423	0.213	1.301	1.182	1.090	1.030
Perkiomen	0.00	1.080	0.221	0.985	0.890	0.818	0.770
Neshaminy	0.00	1.083	0.226	0.985	0.887	0.813	0.765
Croton	2.75	1.137	0.239	1.028	0.920	0.838	0.783
Tohickon	0	1.310	0.251	1.178	1.048	0.949	0.882
Sudbury	3.08	1.085	0.253	0.975	0.865	0.782	0.727
Merrimac	2.65	1.020*	0.259	0.914	0.809	0.730	0.677
Gunpowder	0	0.911	0.308	0.800	0.687	0.602	0.546

* Land and water area.

AS TO EVAPORATION FROM WATER SURFACE AND THE ALLOWANCE THEREFOR.

Notwithstanding the historic researches of Desmond FitzGerald, Past-President, Am. Soc. C. E., on evaporation, and the data which have accumulated in all the years since his results were published, the actual knowledge of the quantity of evaporation from water surfaces is meager. Primarily, this is because there is no certain way of measuring the evaporation from an actual reservoir. In the best planned experiments, conditions differ rather widely from those of water in an open reservoir. The quantity of experimental data, also, is not great or continuous, and is far from adequate for giving a general idea of the allowances that should be made all over the country.

Mr. FitzGerald's experiments at Chestnut Hill gave a mean annual evaporation of 39.1 in.

At the Lawrence Experiment Station, Massachusetts State Board of Health, H. F. Mills, Hon. M. Am. Soc. C. E., found that the evaporation from water in a wooden tub, 17 ft. in diameter, through a period of 3 years, averaged 29.2 in.

Experiments at Fall River, Mass., reported by Mr. A. T. Safford, in a tank 5 ft. 11 in. in diameter and 3 ft. high, in a coffer-dam, observed for 3 years, with a few winter months missing, indicated a mean annual evaporation of 38.7 in.

At Rochester, N. Y., E. A. Fisher, M. Am. Soc. C. E., found that the evaporation from water in a tub, floated on the surface of the Mount Hope Reservoir from 1891-1909, averaged 34 in. per annum. A similar tub on land, with some results missing, indicated 17 in. per annum more evaporation than from the floating tub. This wide divergence indicates the great difference in results from a slight change in exposure. In summer the water in the tubs was warmer than the surface water in the reservoir by 3 or 4 degrees. It is very likely that the actual evaporation from the reservoir is less than is indicated by the records from the floating tub. When the difference between the conditions in the best arranged exposure and those in an actual reservoir are considered, too much weight must not be attached even to the best experimental results.

Comparison of Rainfall Records with Estimated Amount of Evaporation.—F. P. Stearns, Past-President, Am. Soc. C. E., gives the following table:*

"Table Showing Relation of Evaporation to Rainfall.

NOTE: + indicates excess of rainfall: — indicates deficiency.

"Month.	Average Year.			Year of Low Rainfall.		
	Rainfall.	Evaporation.	Excess or deficiency of rainfall.	Rainfall.	Evaporation.	Excess or deficiency of rainfall.
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
January.....	4.18	0.98	+ 3.20	2.81	0.98	+ 1.83
February....	4.06	1.01	+ 3.05	3.86	1.01	+ 2.85
March.......	4.58	1.45	+ 3.13	1.78	1.45	+ 0.33
April........	3.32	2.39	+ 0.93	1.85	2.39	— 0.54
May.........	3.20	3.82	— 0.62	4.18	3.82	+ 0.36
June.........	2.99	5.34	— 2.25	2.40	5.34	— 2.94
July.........	3.78	6.21	— 2.43	2.68	6.21	— 3.53
August......	4.23	5.97	— 1.74	0.74	5.97	— 5.23
September...	3.23	4.86	— 1.63	1.52	4.86	— 3.34
October.....	4.41	3.47	+ 0.94	5.60	3.47	+ 2.13
November...	4.11	2.24	+ 1.87	1.81	2.24	— 0.43
December...	3.71	1.38	+ 2.33	3.55	1.38	+ 2.17
	45.80	39.12	+ 6.68	32.78	39.12	— 6.34"

*Report, Massachusetts State Board of Health, 1890. p. 345.

Mr. Stearns states:

"It will be seen from the facts presented that the monthly rainfall varies much less during the year than the evaporation; also that in an average year the rainfall is 6.68 inches greater than the evaporation. The average year may be divided into two periods, one extending from May to September, inclusive, in which the evaporation is 8.77 inches greater than the rainfall; and the other extending from October to April, inclusive, in which the rainfall exceeds the evaporation by 15.45 inches.

"In the year of low rainfall the evaporation was 6.34 inches greater than the rainfall. During the warmer months, from April to September, inclusive, the excess of evaporation was 15.22 inches, and during the other six months the rainfall was 8.88 inches in excess of the evaporation. These figures indicate that a pond will not lower by evaporation in a dry summer more than about fifteen inches, even if it receives no water from its water-shed."

The following analysis is presented of the figures used by Messrs. FitzGerald,* Stearns,† and Freeman.‡ The first two publications refer to the Sudbury River, and the data used were the same. Mr. Stearns also used Mr. FitzGerald's data on evaporation as a basis for his calculations. The only differences are in the method of applying the data. Mr. FitzGerald based his calculation on the total area, including water, and Mr. Stearns reduced the figures for flow at the outset to a basis of land area, as is done in this paper. In using Mr. FitzGerald's figures, they have been changed by the necessary calculation to make them comparable with the others. Mr. Freeman's figures relate to the Croton River, and those finally reached are in the shape of a diagram from which the values in the following tables have been scaled, with such calculation as necessary to bring them to the uniform basis. Mr. Freeman also used Mr. FitzGerald's evaporation results as a basis for his allowances.

All the figures in the following tables, therefore, rest on Mr. FitzGerald's work. They are of interest as showing the amount of the corrections actually used, and they are also important because these tables and diagrams have been those that have been used most widely in estimating the capacity of other sources.

The storage, in millions of gallons per square mile of land area, computed for no water area and for 6% water area (6.38% of the land area) are given in Table 23.

* *Transactions*, Am. Soc. C. E., Vol. XXVII, p. 253.
† Report, Massachusetts State Board of Health, 1890, p. 335.
‡ Report upon New York Water Supply, 1900, p. 230.

TABLE 23.

Draft, in gallons per day.	FitzGerald. Sudbury River.			Stearns. Sudbury River.			Freeman. Croton River.		
	No water.	6% water.	Difference.	No water.	6% water.	Difference.	No water.	6% water.	Difference.
100 000.......	0.3	6.9	6.6	0.6	8.8	8.2	5	8	3
200 000.......	8.8	15.6	6.8	9.4	18.0	8.6	14	20	6
300 000.......	28.5	35.1	6.6	29.8	36.1	6.3	29	35	6
400 000.......	51.3	56.6	5.3	52.0	57.5	5.5	51	57	6
500 000.......	75.8	79.1	3.3	76.5	80.3	3.8	75	82	7
600 000.......	100.6	107.0	6.4	102.0	107.1	5.1	100	108	8
700 000.......	140.0	157.0	17.0	144.4	161.6	17.2	129	134	5
800 000.......	199.1	215.0	15.9	202.3	219.5	17.2	157	162	5
900 000.......	334.1	342.0	7.9	346.2	352.2	6.0	207	216	9

The figures under the headings "Difference" indicate the additional storage required to compensate for loss by evaporation with 6% water area. These may be conveniently stated in terms of the depth of water over the area of the water surface. The figures reduced to this basis are given in Table 24.

TABLE 24.

Draft, in gallons per day.	Excess Storage in Depth over Water Area, in Inches.		
	FitzGerald. Sudbury River.	Stearns. Sudbury River.	Freeman. Croton River.
100 000........................	6.0	7.4	2.7
200 000........................	6.1	7.7	5.4
300 000........................	6.0	5.7	5.4
400 000........................	4.8	5.0	5.4
500 000........................	3.0	3.4	6.3
600 000........................	5.7	4.6	7.2
700 000........................	15.3	15.5	4.5
800 000........................	14.3	15.5	4.5
900 000........................	7.1	5.4	8.1
Average..............	7.6	7.8	5.5

All this work has been checked by the writer by an independent calculation, which indicates the substantial accuracy of the methods of calculation which are thus summarized. This was done by making tables of corrected flows for the Croton, Sudbury, and Wachusett records. The actual water area was taken into account for each month, the quantity of rainfall on it and the quantity lost by evaporation, using Mr. FitzGerald's figures for all three sources. In this way the calculated run-off was obtained for an area with no water

exposed to evaporation. By similar procedure, the quantity of run-off was calculated from the assumption that there was 0.1 sq. mile of water area for each square mile of land. The storage required to maintain certain drafts was then computed. These results are shown graphically in Figs. 2, 3, 4, 7, 8, 9, 18, 19, and 20. The excess storage, expressed in inches of depth, for an area having 0.1 sq. mile of water area for 1 sq. mile of land area, as compared with no water area, was found to be practically the same for assumed drafts of 200 000, 400 000, 600 000, and 800 000 gal. per sq. mile. For the Croton, the average excess storage required in years of different degrees of dryness was as follows:

80% Year	6.7	Inches.
90% "	7.7	"
95% "	8.6	"
98% "	9.5	"
99% "	10.0	"

The figures are two-thirds of the maximum excess of summer evaporation over rainfall for years of the same degree of dryness. The excess storage required on the Wachusett Reservoir was slightly less than for the Croton, and on the Sudbury slightly more. These differences result from changes in the distribution of the rainfall as much as from variations in the total quantity. It would be easy to introduce refinements in this calculation and extend it, but the accuracy of the data do not warrant it.

Independent Study as to Evaporation.—All the figures thus far given are based indirectly on Mr. FitzGerald's experiments. In the case of three of the streams for which flow data are available, namely, the Croton and Sudbury Rivers and the Wachusett Reservoir, there has been an increase of water area during the period covered by the records. If the excess of evaporation over rainfall on this added water area was large, it would be expected that the records of flow would show the influence of this increase. To investigate this matter, each record was divided into two parts, the latter of which in each case represents a larger percentage of water area. The storages required to maintain flows of 100 000 and 200 000 gal. per sq. mile were taken, and the storage required to maintain the flow in the 95% year found for them. The results are shown in Table 25.

TABLE 25.

	Croton.		Sudbury.		Wachusett.	
	1st series.	2d series.	1st series.	2d series.	1st series.	2d series.
Length of time, in years	24	20	10	12	7	8
Percentage of water area	1.92	3.72	2.56	3.53	2.23	5.85
Storage, in millions of gallons per square mile of land, required to maintain a flow of 0.1 million gallons per square mile of land in 95% year	3.0	3.0	2.0	1.5	0	1.5
Storage, in millions of gallons per square mile of land, required to maintain a flow of 0.2 million gallons per square mile of land in 95% year	10.7	12.1	12.9	8.2	2.4	9.4
Increase in water area	1.80%		0.97%		3.63%	
Increase in storage, 0.1	0.0		− 0.5		1.5	
0.2	1.4		− 4.7		7.0	
Average	0.7		− 2.6		4.2	
Equivalent depth of water over additional exposed area, in inches	2.2		− 15.4		6.7	
Weighting factor	44 × 1.80 = 79		22 × 0.97 = 21		15 × 3.63 = 54	

Weighted average for all three, net loss, 1.4 in.

On the basis of the weighted average, a net loss by evaporation of 1.4 in. is shown. The relative loss would obviously be greater in a drier year. Repeating the calculation for the 98% year, the excess evaporation on a weighted average is found to be 2 in. This is less than one-third of the average quantity deduced in the preceding calculations.

In the Sudbury records the second series clearly represented a less dry time than the earlier series, and a change in this respect was more than enough to offset any influence exerted by evaporation on the increased water surface. In the same way, the second Wachusett series represents a drier period than the earlier one, and the effect of evaporation is probably less than is indicated by these figures. As far as these data go, they indicate that the allowances made by Messrs. Fitz-Gerald, Stearns, and Freeman were at least sufficient for these streams.

Obviously, the amount of this allowance, which is relatively small in these particular cases, and not a matter of the first importance in calculating the storage on these streams, would become greater with smaller rainfall or with greater relative evaporation such as must be anticipated in many places. On the other hand, for some reservoirs,

even in the driest years, the rainfall on the water area will exceed the evaporation.

As to the Method of Applying the Allowance for Evaporation.—The whole process may be conveniently divided into three parts. The first consists in excluding the water area from the computation and reckoning the discharge on the land area only. This was done at the outset with most of the data used in this paper.

The second consists in finding the probable mean yield or mean loss from the water area, and adding it to or subtracting it from the estimated run-off from the land area, thereby obtaining a corrected estimate of the mean annual flow from the whole area. It may be noted that the relative variation in yield from water area is greater than in yield from land area. It follows that, as the water area increases, the coefficient of variation of the mean annual flow will increase. With large percentages of water area, this is a matter that must be taken into account. With only such variations as are represented by forming reservoirs for the development of ordinary catchment areas, the change in the coefficient will not be large, and its effect may usually be overlooked.

The third step is to find the amount by which the evaporation will exceed the rainfall during the period of depletion of the reservoir in a dry year. The amount of this excess, in inches over the whole water area of the reservoirs, represents a quantity of water which must be added to the calculated storage, in order to obtain the total required storage to maintain a given draft, or, in the reverse calculation, it must be deducted from the capacity of a reservoir before calculating the maintainable yield from it.

In the case of the Croton, Sudbury, and Wachusett Reservoirs, on the best available evidence, the amount of this allowance should be between 6 and 10 in. This is considerably less than the maximum evaporation in excess of rainfall in all the dry months of a dry year. This latter, from the best data, amounts to about 15 in. The allowance, therefore, is from one-half to two-thirds of the maximum amount that a reservoir without inflow or outflow would lower in a dry year.

The reason the allowance is less than the full amount of such lowering is that the period of depletion due to draft of water at a steady rate does not coincide with the period during which the evaporation is greater than the rainfall.

For other climatic conditions, it is apparent that the allowance would vary. It will increase with the evaporation and will decrease with the rainfall, and it will increase relatively with the length of the period of depletion. That is to say, with a well-marked seasonal fluctuation in rainfall, the correction for evaporation may be greater than with well-distributed rainfall.

For roughly approximate work, the writer suggests that the allowance for evaporation in a 95% dry year may be estimated as equal to the mean annual evaporation, less two-thirds of the mean annual rainfall. Such a rule cannot be regarded as close, and it is probable that additional data will lead to its modification. On present information, the probable error involved by its use will not be very great, except in the case of large and shallow reservoirs.

Storage on a Tributary.

The ordinary condition of storage is in a reservoir on a main stream, so that all the catchment area is tributary to it. It frequently happens that the best reservoir site, or the actual reservoir, is on a branch stream where only part of the catchment area is tributary to it, and the question arises as to how far the storage on such a tributary is equivalent, or nearly equivalent, to storage on the main stream.

This matter was investigated at Springfield in connection with the Borden Brook Reservoir, which, as a first development, had only one-sixth of the Little River catchment area tributary to it. It was also investigated by Mr. R. R. Marsden and the late Richard Hazen, Jun. Am. Soc. C. E., as a graduation thesis at the Thayer School of Civil Engineering, in 1909.

Storage on a tributary is obviously as useful as storage on a main stream, up to the point where the reservoir would be certain to fill in the driest winters. For streams of the character of those in the East now under discussion, this is represented by about 12 in. of storage for the area back of the reservoir.

Additional investigation, however, has shown that a larger reservoir is filled in the years that precede the driest year; that it is used in maintaining the flow during the driest year; and though it may not refill in the winter following the driest year, that fact is immaterial because enough water will be collected to serve during the year

following the driest year; and, in the years that follow, the reservoir will be refilled before another extremely dry year occurs.

It was found that with 12 in. of storage on the main stream as the greatest quantity which could be counted on to be refilled with certainty each winter, a reservoir on a tributary holding 18 in. from the area back of it, or 50% more than the maximum size that could be refilled every winter with certainty, was practically as serviceable as an equal volume of storage on the main stream. That is to say, on a given catchment area 1 000 000 000 gal. of storage on a tributary is substantially as useful as 1 000 000 000 gal. of storage on the main stream, up to the point where the area tributary to the reservoir will suffice in the driest winters to furnish two-thirds of the capacity of the reservoir. With a larger reservoir, there is some further gain with increasing size, but in a diminishing ratio.

How Far Will it Pay to Go in Providing Storage.

In the past the question has been mainly discussed on the basis of providing storage sufficient to maintain the supply through a period of years as dry as those taken as the limiting condition, usually those from 1879 to 1883. We now have data to make an estimate of the probability of the occurrence of years of various degrees of dryness, and it remains to determine which shall be used. Obviously, it is necessary to provide storage sufficient to maintain the supply in as dry years as any that occur with considerable frequency. It is equally obvious that it will not ordinarily pay to provide storage to maintain the full supply through a year so dry that it will recur, say, only once in 100 years. The chances are that a supply now built will have passed through the whole period during which it is able to maintain its intended service, and will have been reinforced with other supplies before the dry year for which it is built would occur.

It has not been infrequent, in American practice, for cities to have somewhat less than a full supply in very dry years. In some cases, where water is being wasted, a moderate shortage may be a blessing in disguise, for it brings about a study of conditions of supply and a stoppage of waste, which is advantageous to the system. This proved to be the case with the recent dry period in the New York City Works. No such advantage results where the services

are all metered and leaks are reduced to a minimum, but, on the other hand, there is inconvenience and loss from a shortage of water. Nevertheless, it is possible, in a very dry year, to cut off some uses of water and reduce the output, and it will be better to do this once in a long term of years than to spend additional money on storage to be but seldom used.

It has been pointed out that, normally, the consumption of water by a city is steadily increasing, and that the supply available at the reservoir fluctuates from year to year with the rainfall. There is only a moderate probability of a very dry year occurring at the same time that the city reaches the dry-weather capacity of the source. In other words, if the supply is designed so that the full service can be maintained 19 years out of 20, there is only a slight probability that the very dry year which cannot maintain the supply will be one of the same years in which the consumption has grown until it has reached the full capacity of the source.

Another consideration that may be taken into account in cases where several systems are near each other is the possibility of buying water from neighboring cities in a very dry year. Growth is always anticipated to a greater or less extent in reservoir supplies, and in other water-works structures, and the chance that all of a group of cities would require the full quantity provided for each at the same time is small. Then there is the chance of getting temporary supplies of inferior quality in times of great emergency. This is more practicable at the present time because of the possibility of disinfecting the water and reducing the danger of infection.

Impounding reservoirs are very stable structures, and subject to but little depreciation. If 5% is the average annual value of capital invested in them by cities, and it costs $100 per million gallons of capacity to build a reservoir larger, it will cost $5 per annum for the chance of using each million gallons of extra water when it is needed. If the storage is sufficient to maintain the service for 90% of the years, there would be a chance of selling the first additional water in one year in ten. On this basis, the cost of the water, when needed, would be $50 per million gallons, or one-half the cost per million gallons of increased reservoir capacity. In other words, if the value of the chance of using the water in the driest year is worth half the cost per million gallons of building the reservoir larger,

the 90% dry year will logically be used as a basis of calculation. If the value of the chance of using the water in the driest year is equal to the cost per million gallons of building the reservoir larger, it will pay to build for the 95% dry year, and if the chance of using the water is worth two and one-half times the cost per million gallons of building the reservoir larger it will pay to go to the 98% dry year.

There are matters which practically enter into the consideration of this question and are not capable of definite analysis. The beginning of the driest year in a long term, which, on the basis mentioned, will result in a considerable shortage of water if the whole supply is then needed, may not be distinguished in its early stages from an ordinary dry year such as recurs at frequent intervals, and does not result in a shortage of water. When the very dry year comes it may be computed that it will be possible to maintain a supply equal to 95% of the normal supply. However, if, during the first half of the period of depletion, water is drawn at the full rate, it will obviously be possible to draw water at only 90% of the full rate during the last half of that period. If the draft was continued at the full rate for three-fourths of the period, the water remaining would only suffice for 80% of the normal output for the remainder. If the extent of the dry period could be foreseen at its beginning, it would be possible to curtail the use of the water at the beginning of the dry period, so that no great hardship would result; but, if the matter of curtailing use is only taken up after most of the water in the reservoir is gone, there may be serious shortage at the end, to avoid which large expenditures would be justified.

A shortage of this kind has a far-reaching effect, and after it there will be a tendency to uneasiness in the beginning of other periods of drought, even when no shortage of water would result.

Such uneasiness may lead to the expenditure of large sums of money for temporary supplies, built in haste and not well adapted to permanent service; and such supplies may not prove to be finally necessary, for the rains will have broken the drought before they are ready for service. Such emergency developments are unfortunate, and it will be worth while to spend a certain additional sum of money to secure increased storage to prevent the chance of needing them, even though the water thus provided may never be required.

On the other hand, it is difficult to persuade the public that a source of supply is being used to the limit of its proper capacity while water runs over the spillway nine years out of ten, and especially when there has been no recent period of water shortage.

The matter is evidently one that must be considered broadly, and an extreme view cannot be maintained. The wisest course seems to be to take a middle basis of estimate, such as the 95% dry year, but to recognize fully its position, and to be prepared at intervals to meet a moderate shortage in supply.

Application to a Specific Case.

The area of the Croton water-shed is 360.4 sq. miles, of which 19.3 are water and 341.1 are land. The estimated run-off from water area is 9.5 in. and from land area 24.0 in. For 19.3 sq. miles of water the production of water is as great as on 7.6 sq. miles of land, and the whole catchment area produces as much water as 348.7 sq. miles of land area. The total storage, including water held by flash-boards, but excluding water in the bottoms of reservoirs not available for supply, is 104 billion gallons. From this an allowance for evaporation equal to 8 in. in depth over 19.3 sq. miles must be deducted, equal to 2.7 billion gallons. The reservoirs, therefore, have a net available storage of 101 300 million gallons, equal to ·290 million gallons per square mile of area. A line representing the storage is drawn across Fig. 31, and the values in Table 26 are obtained.

TABLE 26.

Year of what degree of dryness.	Maintainable yield in thousands of gallons per square mile per day.	Total yield of catchment area in millions of gallons per day.
80%	1 020	356
90%	970	338
95%	930	324
98%	890	312
99%	869	303

The calculation may be made in another way, using Figs. 33 and 34. The mean average run-off for the Croton River, 349 sq. miles of equivalent land area, at 1 137 000 gal. per sq. mile per day, is 397 million gallons daily, or 1 450 billion gallons per annum. The storage is 104 billion gallons. From this deduct evaporation equal to 8 in. in depth over the water area, 2.7 billions, and add for natural storage

equal to 23 days' supply at an assumed yield of 320 million gallons per day, 7.4 billions, which makes the total net storage, natural and artificial, 108.7 billion gallons, equal to 0.750 of the mean annual run-off.

Referring to Fig. 33 and interpolating between the lines for the coefficient of variation, which is 0.239 for the Croton River, it is found that in a 95% year 82.0% of the mean annual run-off should be utilized, which is equal to 326 million gallons per day. In Fig. 34 it is found that in a 98% year 78.2% of the mean annual flow should be utilized, equal to 310 million gallons per day. These figures check those previously reached, and illustrate a method of computation that would be more frequently used.

It may also be seen, from the position of the point showing the quantity of flow on these diagrams, that the probable maximum time that the reservoir will not entirely fill in a 20-year period is about 5 years, being slightly greater for the larger of the two drafts and slightly less for the smaller one.

These figures mean that, assuming the exact accuracy of the data and methods of computation, with a steady draft of 326 million gallons per day, there will probably be a shortage during some part of one year in twenty. With a like draft of 310 million gallons per day the shortage may be expected in one year in fifty, etc. The figures do not mean that there is only one chance in 50 that the supply will fall below 310 million gallons per day in any given year. They do not mean this because there are other sources of error than those thus far taken into account. Thus there are errors in the measurement of water and in the methods of calculation.

Actual Probability of Shortage in Supply.

If it were required to estimate the quantity of water such that taking all these matters into account there will be only one chance in 20 or 50 that the yield in any given year will fall below it, it ought to be possible to make an approximate estimate of such amounts.

The following is suggested as the general means of procedure, and is presented as an illustration and not with a view to attach importance to the particular figures used. The foregoing figures are plotted on probability paper on Fig. 37, and the line extended crosses the 50% line at 390 million gallons per day, and this will be taken as

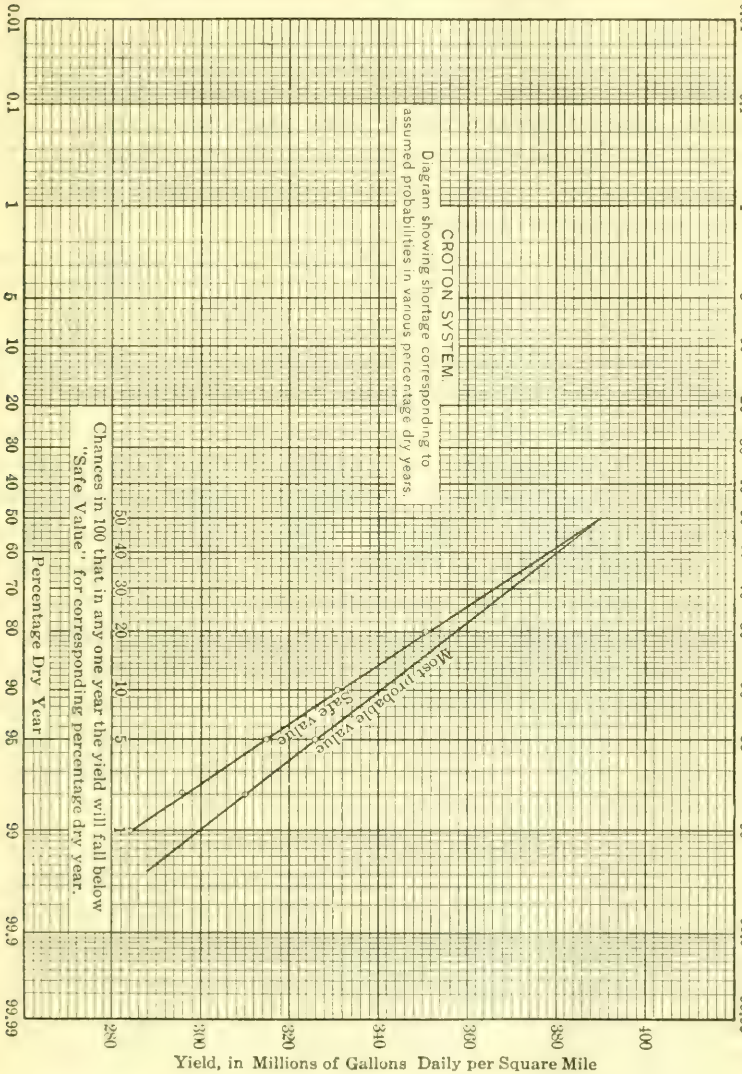

CROTON SYSTEM.
Diagram showing shortage corresponding to assumed probabilities in various percentage dry years.
Chances in 100 that in any one year the yield will fall below "Safe Value" for corresponding percentage dry year.
Percentage Dry Year
Safe value
Most probable value
Yield, in Millions of Gallons Daily per Square Mile
280
300
320
340
360
380
400
0.01
0.1
1
5
10
20
30
40
50
60
70
80
90
95
99
99.9
99.99

FIG. 37.

the starting point for the calculation. It crosses the 99% line at 299 million gallons per day. The difference between the 50% and the 99% year by the normal law of error is 3.45 times the probable error. The probable error in one term, therefore, is $\frac{390 - 299}{3.45} = 26.4$ million gallons per day. This is equal to 6.78% of 390 millions, the starting point of the calculation. This figure may be taken as the probable error in one term of the series of annual available quantities, on the assumption that there is no error in the figure used for the mean annual flow of the stream.

The probable error in the general average for the whole series, with a standard variation of 0.239 and a period of 45 years, is $\frac{0.239 \times 0.674}{\sqrt{45}}$ = 2.4 per cent. The probable error in the calculated mean flow, the storage being above the critical point, as a result of this error, is 0.8 of this, or 1.9 per cent.

It may be assumed that the probable error in the measurement of water is 3%, and that there are errors in calculations and methods amounting to 2 per cent. These probable errors are not cumulative, but will probably offset each other in part. The probable error of the combination will be greater than the probable error of any of the parts, but will not be equal to the sum of the probable errors of the parts. Following the basic method of ascertaining the standard variation and the probable error, it may be assumed that the probable error of the combination is equal to the square root of the sum of the squares of the separate probable errors. The probable error of the combination calculated in this way is:

$$\sqrt{6.78^2 + 1.9^2 + 3^2 + 2^2} = 7.9 \text{ per cent.}$$

For the 99% year the error will be 3.45 times the probable error, or 27.2 per cent. Deducting 27.2% from the starting point of 390 million gallons per day leaves 284 million gallons, and, on the basis taken, we should be justified in assuming that there is only one chance in 100 that the yield will fall below this quantity in any given year. Other values are given in Table 27.

Taking the 95% year as a basis, there is a 5% chance that there will be a shortage in flow in any given year with a steady use of 326 million gallons per day, this being based on the assumed accuracy of all the data and the general average of the whole term. If, in addi-

tion, insurance is to be written against the errors in the general average, in measurements and calculations, to the extent just indicated, then there would be a 5% chance that the yield would fall below 315 million gallons per day in any one year. Fig. 37 shows these two lines plotted on probability paper.

TABLE 27.

Comparative dryness of year.	Ratio of actual variation to probable error.	Total percentage variation.	Corresponding yield.
80%	1.25	9.9	351
90%	1.90	15.0	331
95%	2.44	19.3	315
98%	3.05	24.1	296
99%	3.45	27.2	284

The upper line represents the most probable conditions, and this should be used as a basis to compare different catchment areas with each other and for similar studies. With a longer record for any given area, there is certain to be some change in the position of this line, and the chances are equal that it will be moved up or down.

The lower line represents extra safe or conservative assumptions. The probabilities are that when more data are available it will be found that the maintainable yield is greater than indicated by this line, or, what is the same thing, stated in the other way, to maintain a given yield the required storage will be found to be less than shown. This line is drawn on the basis of not taking chances and resolving all doubts against the probable supply of water. It seems that this second line may be useful in the discussion of the subject. To neglect to consider it is to fail to take into account the full measure of uncertainty that there really is in the first line.

Which line should properly be used as a basis for a water supply project must be a matter of judgment, and will not be discussed at this time. It is important to point out the difference between the two bases and to urge that it shall not be overlooked; and that, whichever line is adopted, it shall be defined so clearly that there can be no misunderstanding as to what is meant.

Conclusions.

The study of storage and maintainable flow of streams involves two classes of relations: First, those which are more or less definite and fixed, and can be analyzed by definite processes; second, those

which rest on conditions too complex to be understood and analyzed by ordinary means of procedure.

The variations of the second class follow, in a general way, the normal law of error, although some well-defined deviations from it have been found.

This paper presents a graphical method of reaching an approximate solution of the problem in probabilities presented by these variations, and permits definite results to be obtained from the data of stream flow and storage. These results are definite, although not exact. They may be used with confidence within limits of probable error, and these limits can be determined.

Arranging the data in this way permits results to be obtained for years of specified degrees of dryness, and thus it is possible to make studies on a more definite basis of the first above defined class of relations. It is found, also, that if the storage required to maintain a flow at all times in an average year equal to 50% of the mean flow of the stream is determined, and if this storage is expressed in terms of days' supply as the assumed rate of draft, then the increased number of days' storage for higher rates of draft are approximately constant for different streams; and, on the other hand, the reduction in the number of days' storage, with equal reductions in the proportionate rates of draft, are nearly the same for all streams.

In a similar manner, the increase in the days' storage, in a year so dry that only one year in twenty is drier than it, is greater than the storage required in an average year by quantities which do not differ widely for different streams. In this way it is possible to form normal inclusive curves of storage for various rates of draft and for years of varying degrees of dryness that will apply to several streams. The actual storage required for any stream will usually be less than the normal by an amount which is approximately constant for various rates of draft and for various degrees of dryness. In this way it is possible to find how the storage required for a particular stream compares with the normal, and afterward to form a judgment of the storage required for other rates of draft and for years of varying degrees of dryness. Thus an estimate may be made which will be more accurate than could be obtained from the records of one stream, however long continued.

It has long been known that in some streams the flow is steady and in others it is variable. This fact is taken into account in this study, and a figure is used as an index of the degree of this variation. This figure, called the Coefficient of Variation, can be obtained from the records of flow of any stream covering a sufficient period, and, when obtained, is used as a basis for comparing the data for that stream, and estimating the probable storage and other matters in connection with relatively high rates of draft. By the use of this Coefficient of Variation it has been found possible to get an approximate expression for the storage required to carry the surplus water of wet years over to dry years, and to put this in such general terms that it applies almost equally well to eastern streams having the least variation in their flows, and to some western streams for which data were examined having many times greater relative variations in their flows.

The records of any one stream, even of those for which the longest records are available, are too short to establish with accuracy the probabilities of the occurrence of very dry years. The records of all the streams used in this study combined into a single series, afford a better basis for estimating the probabilities of the occurrence of very dry years than the records of any one stream. The writer believes that the basis deduced from the records of all these streams is a safer one to use than the records of any stream now having an available record, even when applied to that particular stream. This is especially true where relatively high storages and rates of draft are considered. In other words, the normal storage diagrams, as applied with suitable allowances for local conditions, are believed to afford a more reliable basis for estimating the probable yield of a stream than can be obtained by any method now available from the records of that stream alone.

The methods herein described, therefore, should afford, not only a means of interpreting more accurately the data available for streams that have been gauged for long periods, but should make it possible to make better estimates of the probable yields of streams which have not been gauged, or have been gauged only for short periods, and the performance of which must be judged, for the most part, from other records of streams similarly situated.

The precision of results reached may be disappointing to those who have made calculations of run-off and storage carried to several

decimal places. Such a degree of precision is not to be inferred from any run-off records at our disposal.

The use of the methods herein proposed makes it possible to estimate the probable errors in the results reached; and frank recognition of the large probable errors in many of the results cannot fail to be advantageous.

The methods of analysis herein proposed seem to be capable of application to other engineering problems, and their use will lead to more accurate knowledge of phenomena which contain large and unexplained elements of variation.

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THE DEPRECIATION OF PUBLIC UTILITY PROPERTIES AS AFFECTING THEIR VALUATION AND FAIR RETURN.

By John W. Alvord, M. Am. Soc. C. E.

To be Presented December 17th, 1913.

Depreciation has been discussed so fully since the regulation of public properties has become important, that space will not be taken here to review fundamentals. This discussion is directed to the question of the general relation of depreciation and its effects on the fair return of a utility property, and also, to some extent, to methods of accounting for depreciation in the administration of such properties.

For the general purpose of this paper, it will be considered that the term "depreciation" covers all the losses of value that occur in property, plants, or parts thereof, from wear and tear, obsolescence, or inadequacy. In other words, it will make no difference in this study whether the loss of value arises because the structure is outgrown, becomes obsolete through changes in the art, or is merely worn out. All these various ways by which value is lessened will be classed under the general term, "depreciation".

The Reproduction Method of Valuation.—In dealing with depreciation as affecting valuations, it must be clearly borne in mind that we are discussing only that line of evidence as to value known as

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

the reproduction method or cost new less depreciation. This line of evidence is only one source of information as to value, because plants or properties may or may not be worth what it costs to reproduce them, and no appraisal or valuation is at all complete which relies wholly on reproduction or cost new less depreciation methods. Other lines of evidence are equally important before arriving at value.

The reproduction method, however, is an important line of evidence, and must always be studied; and the relation of depreciation to cost new is therefore vital. This relation is discussed herein.

Depreciation as Affecting the Fixing of Rates.—Recently, the question has been asked, "Should depreciation be deducted from the investment cost of a property before computing fair return?" This question was discussed by C. E. Grunsky, M. Am. Soc. C. E., in his paper entitled "The Appraisal of Public Service Properties as a Basis for the Regulation of Rates."* Mr. Grunsky contends that depreciation should not be deducted for rate-making purposes, but the original investment should be used for the fixing of rates, on the theory that the investment must be maintained intact, first, by the maintenance of the plant, and, second, by a sum set aside for renewals from time to time. The question is also discussed in a paper by Mr. Robert H. Whitten,† of the New York Public Service Commission, who concludes that, for rate-making purposes, the depreciation should be deducted from the reproduction cost. Mr. Samuel S. Wyer,‡ of Columbus, Ohio, expresses the opinion that the cost of reproduction, less accrued depreciation, is not the proper basis for rate-making, but does not make it quite clear whether he means this to apply to cases where the sinking fund for depreciation is in hand or not.

Here, therefore, there seems to be a very serious disagreement, among authors who have written recently on this subject, as to whether or not depreciation should be deducted from the cost new of a property for finding value for rate-making purposes where the reproduction method is adopted as a basis of value. It seems to be desirable, therefore, to present a further study of this question. Certainly there must be in this, as in all other questions relating to this difficult subject of valuation, a just and equitable relation between the public and

* *Transactions*, Am. Soc. C. E., Vol. LXXV, p. 770.

† *Engineering News*, May 8th, 1913.

‡ In his book, published recently, "Regulation, Valuation, and Depreciation of Public Utilities," Chapter 13, p. 185.

the public utility owners, which is founded on rational analysis and common sense.

At the outset, it may be said that the sinking-fund method seems to be an accurate way to compute depreciation where all or most of the life history is known, as it consists largely in finding past depreciation. This is mainly because the sinking fund is without emolument to the owners of the plant, and therefore has in it no element of confusion.

The sinking-fund method of computing or allowing for depreciation consists in determining the proper useful life of the structure or machine under consideration, and setting aside from year to year a sum of money which, with its annual increment of interest, will, at the end of the assumed life, replace the structure or machine in question.

In case a portion of the life has passed away, the present value of such structure or machine is assumed to be, in a general way, the present cost of replacement new, less the accrued amount of the depreciation fund to date.

The sinking-fund method, however, when practically applied to a great variety of structures in a plant of a wide and varied character, is a complicated and difficult way for the accountant to write off depreciation for the future, especially where most of the data must be assumed and where they do not warrant that degree of accuracy that a sinking-fund computation would imply.

It is often found practical, therefore, and rational, to determine past depreciation on the terms of a sinking-fund basis, while future depreciation may be practically set aside on a uniform-increment method for simplification. There seems to be no reason why the two methods cannot be made to correspond, if desired, or why this combination is not as rational, under the circumstances; as the future is quite largely prophecy, in any event.

In dealing with theory, however, it seems best to use the sinking-fund method in illustration, as it appears to be the accurate way in which to think out the governing principles.

Actual versus Theoretical Depreciation Funds.—Let it be clearly understood, first of all, that a sinking fund for depreciation, actually set aside under suitable trust provisions, is to be considered as a part of the property, and, where it is found intact and of proper amount by

the appraiser, it should be thus considered, and no deductions from cost new or reproduction cost, where that method is being used, would be necessary.

Where a proper depreciation fund is not set aside actually, but is only estimated and written off in the accounts, there is no such condition, and the matter of writing it off by the owner in his books amounts to only an opinion of his as to what such depreciation fund should be, but does not at all produce such a fund, or make it available; in consequence of which, an appraiser, using the cost new or reproduction method as one of the means of arriving at the value of the property, and finding no depreciation fund actually in hand or in trust, is obliged to deduct it from the property.

In other words, no amount of accounting or theorizing can make good a depreciation fund which is actually not in hand. A clear perception of this principle will save much confusion of thought.

The Attempt to Simplify the Question.—In order to understand the dilemma which a certain line of thought has been recently attempting to follow in this matter, an effort will be made, first of all, to state the case from such a standpoint.

Probably the most simple proposition which would occur to one first considering this question would be the case where the composite life of an entire plant or property has been estimated; that is to say, where the depreciations of all its component parts have been thoughtfully determined, the probable life of each component part established, its age found, and the amount of a sinking fund which will replace it at the end of its life computed. The average life of these component parts should give the composite life of the plant, at the end of which—theoretically at least—it would be subject to entire renewal; in other words, at that time, supposedly, the original investment would have completely disappeared.

To state more fully this line of thought (which has led to certain perplexities), let it be assumed for the moment that no additions are made to the plant, and that it is the purpose to hold the original investment intact. It is commonly considered in such case that if one computes (but does not set aside) a sinking fund for renewals, its accumulations, year by year, if properly estimated, will represent in a general way the decreasing value of the property, or at least roughly so. If one deducts this sinking fund each year from the original value,

to determine the value on the reproduction basis, and computes the rates which would be necessary in order to pay all charges and a fair return on the same, one would have, theoretically at least, a slowly decreasing valuation, year by year, on which to predicate rates, and the rates themselves would therefore necessarily lessen year by year until, at the end of the composite life of the plant, there would properly be no rates at all, and, theoretically at least, the entire investment would be represented in the sinking fund, if there was one.

In California, under the laws which formerly existed for some years, such conditions seemed to be contemplated, for it was expected that plants would be valued, or might be valued, every year for rate-making purposes. It was the existence of this law that probably led Mr. Grunsky to speculate on this particular problem, and his paper has convinced some students of the subject that the rates should not decrease with the depreciated value of the plant from year to year, but should be predicated on what he calls the "original investment", without deducting depreciation. That this appears plausible on its face, one would not at first be inclined to doubt, but it is believed that closer analysis will show that it is not sound in reasoning.

It should be noted, of course, that a sinking fund itself actually set aside is not a source of revenue to the owner, because its interest accretions are necessary to its own growth and purpose; therefore, it is argued that it may properly receive return outside of its own interest accretions. At the end of the life of a given plant, under this theory, it will be receiving the full rates on the full investment, but with a practically worn-out plant, together with a sinking fund in the bank which will entirely replace it. Theoretically, also, it is argued that, if the owner were to go out of business, he could take the entire fund with him, and consider himself recouped for his property. Of course, he would not be entitled to rates any longer. If it is supposed that he should decide to remain in business, he would immediately have to invest the entire sinking fund again in complete renewals, and receive rates based on the full necessary investment, all of which seems to point superficially to the conclusion that the rates, at all times, should be determined by the value of the undepreciated property.

There is much more to the question, however, than the above simple presentation would seem to indicate.

Perpetual Life.—As a matter of fact, depreciation is not as simple in its practical operation as just stated. In the first place, it is not contended seriously by any one familiar with the subject that a plant usually or normally has a point at which its life actually terminates.

A casual inspection of the life of various structures used by appraisers shows that, in any given plant, a great variety of useful existence is assigned from experience to different structures, so that actually none of the component parts of a plant can be said to terminate at one and the same time, but each part must be renewed independently at such time as the necessity arises. This would result in practically repeated reductions of the depreciation fund, if one actually existed, and the absorption of its funds from time to time into the plant. Therefore, there is no one time at which the depreciation fund actually does or can rise to a very large amount; and it would be practically impossible, under normal conditions, that it should ever grow in amount, even to the larger part of the original investment. As a matter of practical observation, it rarely ever theoretically amounts at any one time to more than from 20 to 25% of the original investment, and more frequently is from 10 to 15%, because, as a matter of practical necessity, renewals must be made and the plant must be maintained and perpetuated, whether the owners would desire it or not. Commonly, therefore, one does not have the condition that the plant is wholly, or even largely, renewed by the depreciation fund at any one time, except under the abnormal circumstances of complete failure through errors in original judgment, or, in rare cases, by reason of duplication or other ignorant lack of conservation.

To illustrate: for instance, in the case of a water-works plant, the boilers, ordinarily, will need to be renewed about once in every 20 years. They would probably be renewed about five times in 100 years, and at the end of about 75 to 150 years the pipe system, theoretically, would be renewed to a considerable extent. The buildings, on the other hand, might be renewed about two and one-half or three times during this average interval, and reservoirs about one and one-half or two times, so that, at the end of 100 years, there might still be a plant of some kind, existing in much the same general

form as the original one, except that those parts which may have become obsolete through changes in the art or method would require that their renewals take other form and character. Therefore, one is dealing practically with a perpetual aggregation of structures, which, not only must be maintained, but must also grow, expand, and enlarge. It is true that in some instances public utility plants have been built, run for a time, and abandoned. This is less and less true as time goes on and such enterprises are better understood. These cases of abandonment are so few as practically to be negligible in reasoning out this matter. The tendency of the times is to conserve and protect such property more and more from destruction or failure.

Utilities Commonly Require Growing Plants.—As a matter of fact, in considering depreciation, the original investment must not only be continued intact by frequent renewals, but, in all ordinary growing cities, must be rapidly increased from time to time by the addition of new capital expended in extensions and enlargements. These new extensions, in turn, have their depreciation, which must be provided for, and they, in turn, must be renewed when their time of usefulness has expired. The actual depreciation, therefore, at any given date in any plant, is the sum of all the depreciations of the various structures then in place, duly considering their age and probable life.

Earning Power of Depreciated Plants.—In considering the matter of the depreciation of a public utility plant, one must not confuse its loss of physical value, as measured by the growth of the depreciation funds, with its ability to have earning power. The progress of a plant in earning power is almost always distinct from its progress in depreciation or appreciation, and though it is generally considered that depreciation of physical property is usually followed by lessened earnings, this is not always true. A plant may not be well maintained, but its earning power may at the same time be well maintained, or even grow rapidly. Theoretically, one may sometimes have the condition (in certain kinds of plants at least), as in the sample illustration used at first, where the depreciation, as measured by the deduction of a sinking fund, becomes greater and greater year by year when plant renewals are not properly made, and where an almost worn out plant may be able to earn much more than the return it earned when new.

Of course, there is a limit to this condition; with certain kinds of plants it is not usually possible; and the sin of too long deferred renewals often brings heavy punishment, yet the fact remains that the earning power of a plant is not always controlled by the defects of depreciation.

Natural Accretions.—A plant or property not only depreciates, but also has sources from which it may appreciate. These appreciations of value have been held to be part of the property, by the Supreme Court of the United States, in the Monongahela Navigation case, and more recently in the case of the Kings County Lighting Company *vs.* The Public Service Commission of New York, First District. One of the reasons the Courts have for favoring the reproduction method or cost new less depreciation, lies in the fact that such procedure includes appreciation as well as excludes depreciation.

When dealing with the valuation of public utilities, it must be kept clearly in mind that a "property" is being considered, and that property may be defined as being all that can be properly transferred to a buyer. Pipes or conduits laid in crowded streets, where many other conduits and tracks, pavements, and heavy traffic would make it difficult to replace them, certainly have a greater reproduction value than they had originally, when the city was unimproved and the streets were open and free for their installation. Right of way and lands, of course, have natural accretions in value, and this is well recognized and understood by the public. What the public does not understand is that similar accretions in value accrue to the property in other items as well as in the increased value of the land.

The Constitution of the United States, in referring to that which must be protected from confiscation, uses the word "property", and not "investment", and the term "property" must necessarily include all the assets which inevitably inhere to, and can be transferred with, the whole entity used and useful for the public.

There are some increments of value produced in connection with an enterprise which originally entailed considerable investment, but cannot be thus transferred, and therefore do not form permanently a part of the property. For instance, a company may have expended a great deal of time, pains, and money, in its original introduction of light, or water, or transportation, for the education of the public as to the value that arises from the use of these facilities. Where

a whole community has been thus educated, it has acquired a fundamental conviction that a utility is really necessary and useful, which conviction, though perhaps developed largely at the expense of a utility company, cannot be transferred as an asset with its property. This is the reason that, in computing costs of development in a rebuilding estimate, it is usually assumed that the public is now already educated in the use of the facility, and would quickly avail itself of the privileges if such facility were reinstalled.

Sinking Funds an Inherent Part of the Plant.—If money has been invested in property which is to be maintained perpetually, and if the public is to be protected by requiring only a fair return based on reasonable rates for the use of this property, such property must be maintained intact by setting aside, as part of the operating expenses, amounts which will sufficiently renew it in part from time to time. In the Knoxville case, the Supreme Court of the United States has held that this is reasonable and proper. If, therefore, one has the right to set aside this money from time to time, theoretically, one should set aside just so much as will maintain the original property in its original form, or the property plus its additions, accretions, and betterments in their total form. To do this will necessitate having on hand, theoretically, part property and part renewal fund. The renewal fund, therefore, is just as much an inherent part of the property as are the tracks, stacks, or boilers, if the property is to be considered as held intact. Where, therefore, one has to value a plant for sale or transfer, and does not find that a renewal fund has been accumulated, or is actually on hand, it is right and proper that one should, so to speak, "fine" the owners, for the absence of this part of the property, by the amount thereof. If the sinking fund for renewal is in the bank or in trust, as well as accounted for on the books of the company, and inherently a part of the property, and in proper amount, one should, naturally, on the other hand, give to the owners of such property the entire reproduction cost of the property undiminished by any depreciation deduction whatever.

It is clear, therefore, that, as far as valuation for the purpose of sale is concerned, it is right and proper that, in the absence of actual sinking funds or any sufficient reserve fund, they should be deducted from reproduction cost or "cost new", when that method is used to

ascertain value. Does not this also hold good in the case of valuation for rate-making?

The Practical Treatment of Depreciation Accounts.—As a matter of fact, few, if any, administrators of public utilities have ever (as far as known, up to date) actually accumulated a sinking fund. Most companies otherwise invest money which would theoretically go to such a fund, because they have thought that such moneys could usually earn a greater rate of interest than they would in a guaranteed sinking fund, and there is the feeling, also, that there would be no difficulty or hazard in relying on the ability of the owner or owners to replace the sinking fund from outside sources from time to time as demands on it occur. This is especially true where the management is more or less personal, and is perhaps not improper, from the point of view of a stockholder, but it means, however, that at all times the property does have within itself, and accounted for on its books, all the elements of the full original value which it had at the start, and to which it is entitled.

To illustrate this situation further, one may take, as an example, a railway having extra rolling stock which is only needed at certain seasons of the year when the traffic amounts to a maximum. It must be admitted that such rolling stock is inherently a proper part of the property, but if the owners decided they could spare this extra rolling stock and should sell it, and should depend on replacing it promptly by some unusual exertion when it was actually needed in the time of maximum traffic demand, they would be in very much the same position as they are when they rely on their ability to replace the sinking fund for depreciation when it is needed. In other words, a part of the necessary property "used and useful to the public" is not present and is not accounted for; and, on a valuation or sale, or even for rate-making purposes, they would have to produce this property, or suffer the diminution necessary to the value of the property by reason of its absence. To state it in another way: a utility company plant is not as valuable to the public without a reserve fund for replacement as it is with such a fund intact and on hand and promptly available.

Absent Depreciation Funds as Affecting Rate-Making.—When one seeks to determine the fair return, through proper rates, on the property of a public utility, it is necessary, in order to protect the public,

to determine carefully the value of the property on which such fair return will be allowed; and if it is found that the owners of the property think it a reasonable and proper policy at all times to take out of the property some part thereof, which is ultimately and finally necessary for its maintenance and continuation, and use that part in other ways, perhaps for private gain, one is under the necessity of denying that they can logically earn rates on the part that is removed and separated from the property to which it belongs.

If a sinking fund for depreciation is on hand and attached to the property, then, by reason of the fact that it itself is not a productive fund to the owners, they should certainly earn rates on it. If, however, they assume that they can take the necessary risks and earn more money on such funds elsewhere, and withdraw such funds from the plant and property, then they must of necessity face the contingency that they cannot be allowed by the public to earn rates on those moneys, on the one hand, and use them for private and outside gain, on the other.

It may be objected that it is a hardship on owners of public utilities, who are able and willing to replace in the property such portion of the renewal fund at any moment that occasion might demand, that they should be made to place in trust such moneys and be denied the privilege of their use for outside enterprise; but it will be easily seen that to accord them this privilege does not ordinarily work out with fairness to the public. A public utility owner, under such circumstances, is tempted to let his plant run down, and withdraw from the property the funds necessary for its renewal from time to time, and use such funds for his other gainful purposes. He may then sometime sell his plant (less reserve fund), and the new owner is obliged to furnish what he has not previously withdrawn. The new owner will naturally demand that rates be made such as would net him a fair return on the undepreciated property under these circumstances. Obviously, here, an injustice would be done, primarily to the public and to the new purchaser as well. The whole procedure thus amounts to the withdrawal by the original purchaser of an unearned dividend, and this is rendered possible by the fact that most utility properties have appreciation as well as depreciation, so that, practically, it is the natural accretion that is withdrawn in this manner. The only practicable way to prevent public utility owners from adopting this procedure is to require that the reserve funds for

renewal shall be kept intact as part of the plant and the property; or that the owners be properly fined, so to speak, by the amount of the funds removed or withdrawn.

Outside Investment of Depreciation Funds.—A great deal has been said in defence of outside investment of depreciation funds. Obviously, reserve moneys can earn a larger rate of interest in many other ways than in guaranteed reserve funds. A guaranteed depreciation fund, especially for long periods, will not be undertaken by bankers or trust companies at more than a $3\frac{1}{2}$ or 4% rate, and for unusually long periods, say 100 years, the rate must be still lower, say $2\frac{1}{2}$ to 3 per cent.

It has been customary with appraisers to recognize this fact in computing sinking funds on a sliding scale, in accordance with the length of life of the structure to be provided for.

Now, these moneys that would be thus set aside in sinking funds are susceptible ordinarily of being invested at much higher rates for general purposes, and where a given result at the end of a given time does not have to be guaranteed, for instance, such moneys may be invested as new capital in new construction and extensions in the very plant itself to great advantage, commanding there often as high a return as 7 or 8%, with, of course, the general risk incident to the enterprise.

It is believed by most administrators that this is an entirely proper way to manage such funds, but it is obviously subject to the reasonable conclusion that the owner cannot have return on it as a "sinking fund" for depreciation, even if he carefully accounts it as such, and at the same time have return on it as betterment to the plant. This would be an obvious injustice to the public.

It is also obvious that another drawback to this procedure lies in the fact that the owner must be willing and ready to finance the replacements and depreciation fund, whenever the occasion therefor arises, and make good for such needs as arise in the non-existing depreciation fund. His temptation will easily be to defer and delay, under these circumstances, perhaps to the great disadvantage of the plant and the public, and although he usually has ample notice of future requirements in such funds, it often occurs that the reserve funds are suddenly necessary for accident or emergency.

If this practice of outside investment of reserve funds is to be ultimately allowed by the utility commissions, the owner's problem becomes an economic one, and is only solved by a close analysis as to whether a depreciation fund, earning return and guaranteed by low rates of interest, is more profitable to the owner than the use of the moneys elsewhere at higher rates of interest, and the resulting loss of return in connection with the plant. It would appear on the face of the problem that, if rates are to include a return on the sinking funds set aside for depreciation, as well as on the depreciated property, it would be more profitable for the owner to maintain the full fund constantly in actual existence, and it is believed that, when this question has been fully understood and discussed, this procedure will be required by the utility commissions.

Present Practice.—The practice, thus far, where reproduction cost is adopted, has been to deduct a theoretical depreciation fund (where one is not actually in hand) from the reproduction cost of the property new, before proceeding to determine the fair return. The question of the correctness of this procedure was not raised until quite recently, and, like a great many other questions connected with the conduct of public utilities, it will probably have to be reasoned out on lines of fairness and justice to both the public utility owner and the public. The rate commissions have not yet discussed this question, nor has it been effectively presented to them, but it is believed that, when discussed, it will be along lines which are here indicated.

Should a Sinking Fund Earn Full Return?—In pursuing this study, the question will be raised as to the propriety of allowing the same full return on sinking funds, when properly set aside in trust as a part of the plant, as is allowed on the plant value itself.

It may be argued, on the one hand, that such funds are free from the hazards of the enterprise proper, that if properly safeguarded or placed in trust, as they might be, they are especially safe and secure, and are free from risk; therefore, they should be allowed only ordinary going rates of interest for secured investments as their part of the fair return on the entire property, and, of course, entirely outside of their own necessary interest accretions.

On the other hand, it may be contended that such funds, generally, are not put in trust, even where set aside, and therefore are subject to call for emergencies in renewals, and partake, in that way, in all the

hazards and contingencies of the plant and property itself, and should accordingly partake of the full returns which the plant and property itself should have.

Inasmuch as the entire question of returns on depreciation funds has never yet been discussed publicly, the attitude of any public utility commission cannot be known in advance, and we will have to await with patience the conclusions of the older commissions which are giving these matters study.

Actual Use of a Full Depreciation Fund.—It may be observed that it is not theoretically possible to expend properly at any one time the full amount of a correctly computed fund for replacement.

Although actual depreciation requirements are not expected to conform to theoretical depreciation funds, nevertheless the two must be so nearly adjusted that funds for renewal closely follow actual requirements. This can only be accomplished by the use of good judgment and experience, in the first instance, supplemented by periodic revisions, as a secondary aid to proper additions to the fund. It would seem that at intervals of not less than 5 years a careful review of the depreciation account of most utilities should be made, and a revision to comply with new conditions effected; oftener would be better in some special cases.

The fact remains, however, that should funds be correctly set aside for renewal and the life of the various structures of the plant be properly estimated, the funds—either sinking fund or as simple increments—could not be wholly or even largely used at any one time; in fact, ordinarily, only a small portion of such fund will be drawn on at any one time. In a sinking fund, if this were not so, the fund would be seriously impaired, as its integrity, to a certain extent, depends on its accretions of interest. Evidently, the short-lived structures will draw on the fund often, and the long-lived structures but seldom; and, where the bulk of the investment is in long-lived structures, it is evident that at least from one-half to three-fourths of the fund might be untouched ordinarily.

This is an added reason, in long-lived plants, why owners now feel inclined to utilize depreciation funds in outside investments, or in betterment to the plant itself; for the remaining portion of the fund that is frequently called on, being small in amount, is easily replaced, and when the larger amounts begin to be needed the fact is long foreseen.

Depreciation Accounts.—Evidently, the keeping of a depreciation account, without setting aside depreciation funds, amounts to only an expression of opinion by the owner as to the lessened value of his property. Such accounts do not finance the depreciation, but, if properly kept, they may tell how much the owner has withdrawn from the value of the plant, and how much he should return, on demand, to make the plant whole.

Past depreciation may very properly be computed on the sinking-fund basis, because this is the close and accurate method when all or most of the life history is known, but the future is much more uncertain. A conservative estimator cannot figure too closely on it; some allowance must be made for the unknown.

The composite life of many water-works plants, for instance, has been found to be between 60 and 80 years. From 0.6 to 0.8% of the total value of the plant, set aside from year to year as an annual increment and put out at interest as a sinking fund, will usually theoretically amortize the principal at the end of the composite or theoretical life.

It is simpler and more conservative, however, to provide a somewhat larger amount in water-works practice, say 1%, as an approach to a straight-line, or even an interest-bearing fund, which may be called "the reserve". Some of the utility commissions are allowing about this amount to be set aside before computing fair return on water-works properties, and it will ultimately be possible, probably, to count on it. Of course, these rates will vary widely in other forms of public utilities; they are cited here only by way of illustration.

In practice, the various structures having different lengths of life should be grouped, so that those of the same life are aggregated, and a separate depreciation account should be opened for each group.

The theoretical sinking-fund amount may be computed for each group and entered each month, so that the sum of all the groups would show the amount due to the plant by the owner at any given time. From time to time adjustments will have to be made to correct for errors in judgment as to future life.

If a simple percentage increment is used, the process will be more simple but less accurate, and hazard and unusual accident may be better and more liberally provided for, but the prophecy as to life will not be closer than it can be in the sinking-fund method.

When renewals are made, the depreciation account should be debited with the outside capital replaced in the plant by the owner, and credited by the cost of the improvement.

Should a sinking fund or a reserve fund actually exist, of course, the replacement expense is directly withdrawn from the same in cash.

Summary.—To conclude, then, it has been argued as follows:

1st.—That if a sinking fund or a reserve fund for depreciation is actually kept in the bank or in trust as part of the property, it should, if properly computed and accurately kept, receive the same rate of fair return as the remainder of the property "used and useful for the public".

2d.—That if these funds are for any reason detached or withdrawn from the property and used by the owner elsewhere, or in private gain, or even as new capital invested in the plant itself, he cannot hope, as a matter of proper protection to the public, to receive return on a reserve fund which is not actually in hand and at the same time use such funds for other personal gain.

3d.—That the past depreciation may be computed accurately on the sinking-fund basis, as all the facts of the past are known, and the sinking fund is the most accurate method of computing depreciation, but for the future, in which the facts are yet unknown, it is perhaps better to use the simpler method of an annual increment which will average the sinking-fund rate.

4th.—That depreciation accounts should be kept by groups having similar life, and revised from time to time as the future is more clearly revealed. That such accounts are only estimates of what the owners owe the property, if the actual funds are not in hand.

5th.—That though it is not now considered improper to use reserve or sinking funds allowed for depreciation for private gain, in so doing the owner will in all probability deprive himself of their return earning power as part of the plant and property.

It may be said, frankly, that all the principles which it is endeavored herein to reason out are not yet generally accepted; indeed, the question of allowing fair return on an actual existing sinking fund for depreciation has not as yet been seriously raised.

It is believed, however, that this question must soon be generally discussed, and it has been the endeavor in this paper to reason out in advance the method by which it is believed it will be logically settled.

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PAINTING STRUCTURAL STEEL: THE PRESENT SITUATION.

By A. H. Sabin, Assoc. M. Am. Soc. C. E.

To be Presented January 7th, 1914.

The corrosion of structural metal (principally steel) by atmospheric and other natural causes is a subject which has long been of importance to the engineer. A few years ago, the greatly increased use of concrete structures aroused the hope that danger from such corrosion would be much reduced; but unarmored steel seems to be used as much as ever. Concrete has not taken its place, but has made an entirely distinct place for itself. Much has been written, and much has been done, relative to the protection of steel; but improvement has been slow, progress being made step by step.

The writer can remember when corrugated iron was introduced, some thirty years ago, that it was common practice to send out with a shipment a suitable quantity of powdered iron oxide to be used as a pigment, with directions for mixing it with oil and applying it as a paint. It was supposed that, because it contained iron, it was a proper paint to apply to iron, like "applying the hair of the dog to cure the bite" (which the writer has also seen done).

Some years ago, Mr. G. W. Thompson attempted to classify pigments, as to their relation with iron, by suspending them in water and immersing pieces of iron or steel in these mixtures. The results

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

were somewhat surprising; some of the pigments which common experience approved, seemed to increase corrosion in this condition, and others, known to be useless in protective paints, seemed to be much better for preventing it. Lampblack, for instance, was the worst in provoking corrosion, and white zinc or pulverized chalk prevented it. This was probably due to the fact that lampblack contains, condensed on the surface of its particles, considerable carbonic acid which is the most generally active agent in the corrosion of iron, and white zinc and chalk are basic substances by which iron is not rusted; however, the carbonic acid in lampblack is displaced by grinding in oil, and the well-known lack of durability in paints made of white zinc and chalk prevents their good qualities from coming into action.

So great is the need of more knowledge as to the value of pigments in paints, and their mode of action, that nothing promising new information is neglected. A committee of five chemists from different parts of the United States, with the approval of the Society for Testing Materials, made a series of tests of the principal pigments, and of some other substances, on steel immersed in water; and, as was to be expected, arrived at substantially concordant results. These results, as has been stated, were of no value from the standpoint of the paint-maker, being inconsistent with the known value of the pigments when ground in oil or varnish. When the report was published, however, the pigments were classified, according to their water value, into three groups, namely, inhibitors, indeterminates, and stimulators. This was the origin of the use of these now well-known words in paint terminology. It was expressly stated in the report that this was a classification as regards water only; but the names were so convenient and so tempting that those not familiar with the subject, and also many who saw their value for advertising purposes (two quite distinct classes), put them into common use to classify pigments in oil. It is obvious that any classification of pigments in oil should be based on their behavior in oil, and if, as must be conceded, this is radically different from water tests, the latter should not be regarded. All this investigation began some years ago; meanwhile, numerous young men, mostly students working under the supervision of their teachers, have made brief and generally inconclusive studies of paints, and almost without exception have used these indefinite terms, inhibitors and stimulators. Patents have even been

taken out—which, in the writer's opinion, are not only worthless but invalid—covering the use of old and well-known pigments. What is worse, every maker of a paint nostrum assures his hearers or readers that his particular paint absolutely inhibits rust, and that everything else stimulates it. This is the whole history of this jargon about inhibition and stimulation; it never had any particular value to the consumer, and it is generally used to mislead him.

It is obvious that in a good paint the pigment particles are enveloped in a film of oil; they do not come in contact with the iron; if they did, the paint would peel off, for no dry pigment adheres well to metal. It is as true to-day as it has been in the past that steel rusts because air and moisture act on it; and paints are used to keep air and moisture from it. They do not inhibit rusting, except as they inhibit the cause of it.

The important practical question is whether paints have been or can be improved as to being non-porous and durable. This is essentially dependent on the relation between the pigment and the oil. As to the true nature of this relation, very little is known; but something is known about its visible manifestations. It is known, for instance, that 1 lb. of dry red lead mixed with $\frac{1}{4}$ lb. of oil makes a paint of ordinary consistency, and 1 lb. of dry lampblack requires at least 6 or 8 lb. of oil, say, thirty times as much, or making allowance for difference in density, six times as much, as the red lead. Similarly, 1 lb. of white zinc takes twice as much oil to make a paint as 1 lb. of white lead; and white lead takes nearly twice as much as red lead. These are things we know; but we have no idea why they are so. Again, red lead, which is an oxide of lead, makes an excellent paint for iron; oxide of iron is neither very good nor very bad; oxide of manganese is bad. Our knowledge of paints is as yet largely empirical; chemists dislike to admit this; for, like everybody else, they hate to confess that there is anything they do not know, and thus when a new theory is offered some of them make a great rejoicing over it without first finding out whether or not it agrees with the facts. Where we are gaining is in more general appreciation of the value of the proper application of paint, better preparation of surface, more confidence in good paint rightly used, and in the better preparation of paint materials. For instance, in the older books, and until about twenty years ago, we find analyses of red lead showing as

low as 55% of true red lead, with 45% of litharge. Red lead is made from litharge, and the presence of the latter is not a sign of adulteration, but of incomplete conversion. At the same time other samples showed as high as 80% of true red lead. As is well known, there was much difference of opinion in those days as to the value of red lead as a paint for iron; though most users liked it, some thought it poor stuff. It is now known that its value depends on the quantity of red lead it contains. Coarse red lead always contains litharge, because the litharge in the middle of a large particle is never oxidized. It was observed that the finer the red lead, the better it was, and so a demand arose which forced the manufacturers to make higher grades; now they are grinding their litharge to an impalpable powder before roasting it, with the result that 94% of true red lead has been on the market for some years. Then an unexpected fact was developed. The old red lead when mixed with oil would set in a day or so—often in a few hours—into a cement, just like plaster of Paris and water; this tendency made it work with difficulty and unevenly in application, and its coarseness gave it a tendency to run; but the new, or high grade, article is inactive to oil, and brushes out smoothly like a house-paint. This enables the painter to cover 50% more surface with the same quantity and still get a coating having a uniform thickness which gives more protection than the thin portions of the paint formerly used. This secures greater economy, even at a slightly greater cost per gallon; and this is an economy not only in the cost of the paint, but in the labor, because the paint works more easily, and a man can cover more surface in a day; it also requires less skill, and therefore, a less highly paid man, to do good work. For the last year or two, red lead ground in pure linseed oil has been offered to the trade as a paste ready to be thinned with more oil; such a paste keeps for a year or more, or indefinitely as far as known, like white lead paste. Its use saves time and waste in mixing, and, being ground through a mill, the mixture is perfect, which is not the case with hand-mixing; and, as it avoids the presence of a dusty pigment, it is more sanitary.

The only serious objection to the use of such red lead is that it dries more slowly than the older kinds. This can be obviated, however, by the use of a little japan drier. There is a well-founded prejudice against the use of excessive quantities of drier in any paint; but it

should be remembered that red lead paint mixed in the (standard) proportion of 28 lb. of pigment to 1 gal. of oil, contains 20¼ lb. of pigment per gallon of mixed paint. If this pigment contains 15% of litharge, it has 3 lb. of litharge per gallon. Now, ordinary, good, lead japan driers, or lead and manganese driers of approved quality, contain the equivalent of 1 lb. of litharge in about 3 gal. of drier; and 3 lb. of litharge will make 8 or 10 gal. of drier. To make 1 gal. of mixed 94% red lead paint dry requires only 1 pint of drier; the rest is excess. It is much safer to add the desired quantity of drier. It may be asked why the litharge in the 94% red lead is not more active; it is probably because, when the peroxidation of the lead has been carried so nearly to completion, the particles of litharge are enveloped so completely by a dense coating of true red lead that the oil does not reach them. This is obviously not the case with the commoner and less thoroughly oxidized pigment.

It has sometimes been suggested, by those not very familiar with the chemical questions involved, that the litharge is the essentially valuable part of the paint, and that the red lead is only an inert extender. This is not so. The whole history of the subject shows that the improvement in red lead for paint during the last twenty-five years has been made by reducing the litharge contained in it; litharge alone, or used with other pigments, has not been satisfactory, though orange mineral, which is red lead free from litharge, is most excellent, and would be used if its cost were not so great. Further progress will undoubtedly produce red lead with a lower percentage of the protoxide; in fact, the 94% red lead now in the market usually contains much more than 94% of true red lead.

Progress has also been made in our knowledge of linseed oil. Within a few months, the American Society for Testing Materials has adopted specifications for North American raw linseed oil, which is of better quality than that made from South American seed. These specifications are the result of a great deal of work by many of the best oil chemists, and it is now possible for any good analyst to tell whether or not an oil is pure and good. Methods of paint analysis are in general being standardized; and a vast amount of work is going on in Germany and England as well as in the United States, on the chemistry and nature of drying oils. At present linseed oil

has adulterants, but no substitute; China wood oil is a valuable drying oil, more valuable for some purposes than any other, but, as an oil for ordinary paints, it is used, as far as the writer knows, only to cover up the use of non-drying oils which must be regarded as adulterants. At present prices, it is not likely to be used even in this way. Fish oil is used to some extent, as it always has been, in paint for roofs and smokestacks; but one should not be disturbed by talk about the "newer paint oils", for, except China wood oil, there are none.

In closing, it may be well to mention that the Committee appointed by the American Society for Testing Materials has made a final report on the condition of the paints on the Havre de Grace Bridge; as is well known, this bridge was painted six years ago by a committee of that Society, which committee included several members of the American Society of Civil Engineers. This report describes three of the paints as excellent; two of these were straight red lead in oil, and the third was red lead, with about 15% of a pulverized silicate added, in oil, the red lead being about 98% true red lead. Nine other paints, of varying composition, are reported as affording generally effective protection to the structure. As all these paints were carefully applied, it is fair to conclude that the durability of any good paint may be increased one-half, and probably doubled, by proper care in its use as compared with average practice. It is only by continually reiterating this fact that we shall ever secure the most elementary and fundamental requirement for the economical treatment of structural steel.

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STRESSES IN WEDGE-SHAPED REINFORCED CONCRETE BEAMS.*

By William Cain, M. Am. Soc. C. E.

In the design of reinforced concrete walls, it is often necessary to find the stresses in beams with faces inclined to each other, as in the toes, heels, face-slabs, and counterforts of such walls. In other cantilever constructions, the upper and lower faces are often inclined to each other, so that the subject is one of importance, and a practical solution is offered in this paper.

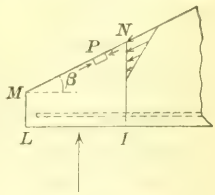

Fig. 1.

First consider the beam, Fig. 1, the upper face of which is inclined at an angle, β, to the lower face, supposed to be horizontal. This beam may be supposed to be the toe of a reinforced concrete retaining wall, and to be subjected to a soil reaction, acting vertically upward, which produces shear and also stresses due to the bending moment, in any vertical section, $N\ I$.

To effect a practical solution, it will be assumed that all the compressive bending stresses act parallel to the top face, $M\ N$, down to the neutral axis. This is the direction of the stress at any point of the upper surface, $M\ N$; for, consider a small rectangular parallelopiped of the concrete at P, with faces parallel and perpendicular to $M\ N$. There can be no shearing stress on $M\ N$, as no part of the beam extends above $M\ N$ to produce shear, and there is no external

* This paper will not be presented at any meeting of the Society, but written communications on the subject are invited for subsequent publication in *Proceedings*, and with the paper in *Transactions*.

force acting on $M\ N$ except the atmospheric pressure, which does not exert any friction on the face. It must follow that there can be no shear on the planes at right angles to $M\ N$, as unit shears on planes perpendicular to each other are equal.* Consequently, the compressive stress on a plane at P, at right angles to $M\ N$, is normal to it, or parallel to the face. This conclusion has been proved experimentally by Messrs. Wilson and Gore, in their exhaustive experimental work on india-rubber model dams.† They state, as one conclusion: "The maximum principal stresses near the down-stream face act on planes normal to that face," and add in a foot-note, "This agrees with Rankine's statement and with the theorem demonstrated by Mr. M. Levy." In the discussion on that paper, the same point was brought out by several speakers.

It is then plain that the compressive stress at N, Fig. 1, similarly, acts parallel to the face, $M\ N$. If this were a homogeneous beam, the tensile stress at I would similarly act parallel to the lower face. Consequently, in going from N to I, the intermediate bending stresses would gradually change their direction from $M\ N$ to $L\ I$.‡ Hence the foregoing assumption, that all the compressive stresses are parallel to $M\ N$, is to be regarded only as an approximation necessary to derive workable formulas.

In justification of its use for reinforced beams, however, it may be stated that the neutral axis is generally above the mid-point of $N\ I$, and, for small percentages of steel, much higher; so that the area under compression is often only one-third of the whole area of the cross-section, or even less. Further, the resisting moment of the compressive stresses is mainly due to the larger stresses near N, with their longer arms, and such stresses are nearly parallel to $M\ N$. Finally, and most important of all, the assumption is always on the side of safety, as will appear more fully later. The assumption is evidently near the truth for small values of β, but departs more from the truth as β increases, and possibly should be limited to values of β below some limit, say 45°, assumed arbitrarily.

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* See Merriman's "Mechanics of Materials," p. 263; also "Stresses in Masonry Dams," by the writer, *Transactions*, Am. Soc. C. E., Vol. LXIV, pp. 220-221. In this article, the directions and amounts of the principal normal stresses, at various points of a horizontal section of a dam, are computed.

† *Minutes of Proceedings*, Inst. C. E., Vol. CLXXII, Session, 1907-1908, Part II.

‡ The same state of affairs exists in the so-called "beams of equal strength," having variable depth, where the ordinary theory of the books is plainly inadequate.

When the external force of Fig. 1 acts downward, the compressive area is below the neutral axis, and the reinforcement will be placed parallel to and near $M\ N$. All the compressive stresses now act parallel to the lower face, as in the common theory.

The usual hypotheses, that no tension exists in the concrete on the reinforced side of the neutral axis, and that plane sections before stress will remain plane sections after stress, will be adopted; but the latter hypothesis cannot be expected to apply very closely when β is large, particularly when it is near 90 degrees.

A general solution will now be given which includes every possible case. All special cases can be at once derived from this general solution.

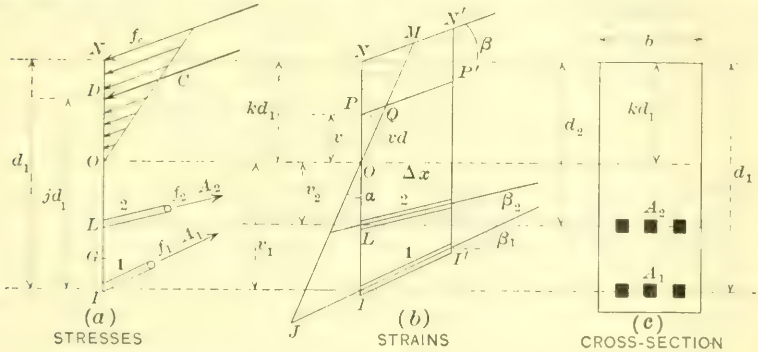

FIG. 2.

In (*a*) and (*b*), Fig. 2, are shown two longitudinal sections, and in (*c*), a section of a part of a beam subjected to stress. $I\ N$ represents a section of the beam taken always parallel to the direction of the loads, which may be weights, soil reactions, earth thrusts, etc. The shear due to the loads thus acts along $I\ N$, and the moment is the same for any point of the section.

For the breadth, b, let A_1, A_2, . . ., represent the areas of the cross-sections (taken at right angles to the axes) of the bars, 1, 2, . . ., at depths d_1, d_2, . . ., respectively.

Let f_1, f_2, . . ., represent the unit stresses in the bars, 1, 2, . . ., so that the total stresses in the successive layers of bars, 1, 2, . . ., for the breadth, b, are $f_1\ A_1$, $f_2\ A_2$, . . ., respectively.

The angles, β, β_1, β_2, . . . (expressed in radians), are those made by the surface, $N\ N'$, bars 1, bars 2, . . ., respectively, with the normal to the section, $I\ N$.

Let O be the neutral axis and D the point where the resultant, C, of the compressive forces (all acting parallel to $N\ N'$) meets $I\ N$.

Let $N\ O = k\ d_1$, $D\ I = j\ d_1$, $O\ I = v_1$, $O\ L = v_2$, etc.

$I'\ N'$ represents a section parallel to $I\ N$, Fig. 2 (*b*), and at a perpendicular distance, $\Delta\ x$, from it. The "fiber," $P\ P'$, parallel to $N\ N'$, of concrete, will be supposed to have an area equal to the section made by the plane $I\ N$, $\Delta\ a$; and the distance, $O\ P$, will be called v. Thus the area of a right section of the fiber is $\Delta\ a$ cos. β; and, if f is the unit stress on a right section of the fiber, $P\ P'$, the total compressive stress on the fiber will be ($f\ \Delta\ a$ cos. β).

After strain, suppose the plane section, $I\ N$, rotates relatively to $I'\ N'$ through the angle, α, to $J\ M$. The section, $J\ M$, will thus be supposed to be plane, as in the ordinary theory.

For any fiber, whether of concrete or steel,

$$\text{unit stress} = \frac{\text{change of length of fiber}}{\text{length of fiber}}\ E \ldots\ldots\ldots (1)$$

where, E = modulus of elasticity of fiber.

Let E_s = the modulus of elasticity of steel,

E_c = " " " " " concrete,

and,

$$n = \frac{E_s}{E_c} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Within working limits of stress, and for the very small values of α corresponding to very small values of $\Delta\ x$, the change of length of $P\ P' = P\ Q = v\ \alpha$ sec. β, very nearly*; hence the unit stress, f, on this fiber, $P\ P'$, by Equation 1 is

$$f = \frac{P\ Q}{P\ P'}\ E_c = \frac{v\ \alpha \text{ sec. } \beta}{\Delta\ x \text{ sec. } \beta}\ E_c = \frac{v\ \alpha}{\Delta\ x}\ E_c.$$

Hence, as this unit stress on a right section of the fiber acts on the right sectional area, $\Delta\ a$ cos. β, the total stress on the fiber is

$$\frac{v\ \alpha}{\Delta\ x}\ E_c\ (\Delta\ a \text{ cos. } \beta),$$

and its component perpendicular to $I\ N$ is

$$\frac{E_c\ \alpha \text{ cos.}^2\ \beta}{\Delta\ x}\ (v\ \Delta\ a).$$

* In the triangle, $P\ O\ Q$, by the law of sines, $P\ Q = \frac{v \text{ sin. } \alpha}{\text{cos. } (\alpha + \beta)}$. As α tends toward zero, this approaches $\frac{v\ \alpha}{\text{cos. } \beta} = v\ \alpha$ sec. β.

The sum of such components on the compressed area of depth, $k\ d_1$ and breadth, b, is

$$\frac{E_c\ \alpha \cos.^2 \beta}{\Delta x} \sum_0^{kd_1} (r\ \Delta\ a) = \frac{E_c\ \alpha \cos.^2 \beta}{\Delta x} \left(\frac{1}{2}\ b\ k^2\ d_1^2\right),$$

since $\sum_0^{kd_1} (r\ \Delta\ a) =$ the statical moment of the area under compression about the neutral axis $= b\ k\ d_1\ \frac{1}{2}\ k\ d_1$.

For the layer of bars 1, at I, similarly, the unit stress is

$$f_1 = \frac{\Delta\ I}{I\ I'}\ E_s = \frac{r_1\ \alpha \sec.\ \beta_1}{\Delta\ x \sec.\ \beta_1}\ E_s = \frac{E_c\ \alpha}{\Delta\ x}\ (n\ r_1).$$

Also, as the area of a right section of bars 1, for the breadth, b, is A_1, the total stress in the bars 1, is

$$\frac{E_c\ \alpha}{\Delta\ x}\ (n\ r_1\ A_1).$$

Similarly, the stresses in bars 2, 3, . . ., are

$$\frac{E_c\ \alpha}{\Delta\ x}\ (n\ r_2\ A_2),\quad \frac{E_c\ \alpha}{\Delta\ x}\ (n\ r_3\ A_3).\ .\ .\ .$$

As all the loads on the beam were supposed to act parallel to $I\ N$, the part of the beam to the left of this section is in equilibrium under the loads and reactions acting on it and the internal stresses along $I\ N$. For equilibrium, the sum of the components of the stresses perpendicular to $I\ N$ must be zero. Therefore,

$$\frac{E_c\ \alpha}{\Delta\ x} \cos.^2 \beta \left(\frac{1}{2}\ b\ k^2\ d_1^2\right)$$
$$= \frac{E_c\ \alpha}{\Delta\ x}\ n\ (r_1\ A_1 \cos.\ \beta_1 + r_2\ A_2 \cos.\ \beta_2 \ .\ .\ .).$$

From Fig. 2,

$$r_1 = d_1 - k\ d_1,\ r_2 = d_2 - k\ d_1,\ .\ .\ .\ ;$$

hence, on substituting these values, striking out the common factor, and reducing, we derive,

$$\frac{1}{2} \cos.^2 \beta\ b\ d_1^2\ k^2 + n\ d_1\ (A_1 \cos.\ \beta_1 + A_2 \cos.\ \beta_2 + \ .\ .\ .)\ k$$
$$= n\ (d_1\ A_1 \cos.\ \beta_1 + d_2\ A_2 \cos.\ \beta_2 + \ .\ .\ .) \qquad (3)$$

From this quadratic in k, the value of k is computed, and thus $k\ d_1 = O\ N$ can be found and the neutral axis located. Also, as the compressive stresses are uniformly varying, $D\ N = \frac{1}{3}\ O\ N$; therefore,

$j\ d_1 = d_1 - \frac{1}{3}\ k\ d_1$; and

$$j = 1 - \frac{1}{3}\ k \qquad (4)$$

The Resisting Moment, M_s, of the Steel.—The moment, M, at the section, $I\ N$, due to the external forces, is equal to the resisting moment of the stresses acting along the section. Calling the perpendicular distances from D to bars 1, 2, . . ., p_1, p_2, . . ., respectively.

$$M_s = f_1\ A_1\ p_1 + f_2\ A_2\ p_2 + \ldots, \qquad (5)$$

where, $p_1 = j\ d_1 \cos. \beta_1$, $p_2 = D\ L \cos. \beta_2$, etc.

Now, as $f_1 = \frac{E_c\ \alpha}{\Delta\ x}\ n\ v_1$, $f_2 = \frac{E_c\ \alpha}{\Delta\ x}\ n\ v_2$, . . . , it follows that

$$f_2 = \frac{v_2}{v_1}\ f_1,\ f_3 = \frac{v_3}{v_1}\ f_1, \ldots, \qquad (6)$$

or the unit stresses in the bars vary directly with the distances from the neutral axis. The unit stresses in the interior bars will thus always be less than f_1, so that such an arrangement of bars is uneconomical.

On substituting Equation 6 in Equation 5,

$$M_s = f_1\ \left(A_1\,p_1 + \frac{v_2}{v_1}\ A_2\,p_2 + \frac{v_3}{v_1}\ A_3\,p_3 + \ldots\right) \qquad (7)$$

If preferred, after locating the point, D, on a drawing, the perpendiculars, p_1, p_2, . . ., can be measured to scale; otherwise, they may be computed readily by the formulas given.

If the resisting moment of the steel, M_s, is less than that of the concrete, M_c, for assigned maximum unit stresses, then the moment, M, of the external forces is put equal to the right member of Equation 7, the value of f_1 ascertained, and, from Equation 6, the values of f_2, f_3, . . ., are computed. The stresses in bars 1, 2, . . ., are thus $f_1\ A_1$, $f_2\ A_2$, . . .

Otherwise, if a certain value is assigned to f_1, as 16 000 lb. per sq. in., and A_2, A_3, . . ., are assumed, from Equation 7, A_1 can be computed. For rough computations, A_2, A_3, . . ., may often be ignored, in which case we can write,

$$M_s = f_1\ A_1\ p_1 = f_1\ A_1\ j\ d_1 \cos. \beta_1.$$

The Resisting Moment, M_c, of the Concrete.—To compute M_c, the position of the resultant, R, of the stresses in the bars, must first be found. The magnitudes of the forces acting on the bars 1, 2, 3, . . ., are

$$f_1\,A_1,\ f_1\ \frac{v_2}{v_1}\ A_2,\ f_1\ \frac{v_3}{v_1}\ A_3, \ldots,$$

and, as these are proportional to f_1, the direction and line of action of R are the same for any value of f_1 and hence for $f_1 = 1$.

Let H = the component of R perpendicular to $I\ N$ when $f_1 = 1$; then

$$H = A_1 \cos.\ \beta_1 + \frac{r_2}{r_1} A_2 \cos.\ \beta_2 + \ldots$$

Suppose the resultant cuts $I\ N$ at G; then, taking moments about D,

$$H\ .\ D\ G = A_1 p_1 + \frac{r_2}{r_1} A_2 p_2 + \frac{r_3}{r_1} A_3 p_3 + \ldots$$

The right member, presumably, has already been computed in applying Equation 7; hence $D\ G$ is quickly ascertained and the point, G, located.

Call the maximum unit stress on the concrete at N, f_c; the unit stress on the fiber, $P\ P'$, at P is thus $\frac{f_c}{k\ d_1}\ r$. This acts on the area $(\Delta\ a\ \cos.\ \beta)$; hence the stress on the fiber is

$$\frac{f_c}{k\ d_1}\ r\ \Delta\ a\ \cos.\ \beta,$$

and the sum of such stresses is

$$C = \frac{f_c}{k\ d_1} \cos.\ \beta \sum_0^{kd_1} (r\ \Delta\ a) = \frac{1}{2}\ \frac{f_c}{k\ d_1}\ \cos.\ \beta\ b\ (k\ d_1)^2.$$

Therefore, $C = \frac{1}{2} f_c\ b\ k\ d_1 \cos.\ \beta$.

Taking moments about G,

$$M_c = \frac{1}{2}\ f_c\ b\ k\ d_1 \cos.^2 \beta\ \overline{D\ G} \ldots\ldots\ldots\ldots\ldots\ldots (8)$$

If, for assigned maximum values of f_1 and f_c, $M_s > M_c$, the beam is over-reinforced and M is placed equal to the right member of Equation 8, as its strength is now limited by that of the concrete. This case rarely occurs in practice.

As an illustration of the application of the formulas, take the counterfort, $B\ M$, Fig. 3, attached to the face-slab, $N\ M$, and suppose the counterfort to be subjected to a horizontal earth thrust of 123 750 lb., acting to the left and 9.06 ft. above N, giving a bending moment at N of 13 454 100 in-lb. The section, $N\ B$, corre-

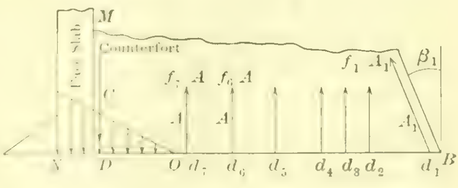

FIG. 3.

sponding to $N\ I$ of Fig. 2, is taken parallel to the load (the earth thrust), and is therefore horizontal.

The width of the counterfort is $b = 18$ in. The inclined bars have a total sectional area $= A_1 = 9.45$ sq. in., and the vertical bars, a common area, $A = 0.784$ sq. in. Using the foregoing notation, $\beta_1 = 23° 58'$, $\beta_2 = \beta_3 = \ldots = \beta_7 = 0$. The distances, d, were measured from N, or from the front face of the vertical slab: $d_1 = 128$, $d_2 = 108$, $d_3 = 100$, $d_4 = 92$, $d_5 = 76$, $d_6 = 60$, $d_7 = 44$, all in inches. Assume $n = 15$.

On substituting known values in Equation 3, we derive $k = 0.311$. Therefore, $j = 1 - \frac{1}{3}\ k = 0.896$; whence $N\ O = k\ d_1 = 39.8$ in., $D\ B = j\ d_1 = 114.7$ in.; also, $N\ D = \frac{1}{3}\ N\ O = 13$ in.

On subtracting $N\ O = 40$ from $d_1, d_2, \ldots$, we derive v_1, v_2, etc. The perpendiculars, $p_1, p_2, \ldots$, from D on bars 1, 2, ..., are $p_1 = j\ d_1 \cos. \beta_1 = 105$, $p_2 = d_2 - N\ D = 95, \ldots$, respectively.

From Equation 7 we have, $13\,454\,100 = 1\,164\ f_1$; whence $f_1 = 11\,500$ lb. per sq. in.; from Equation 6, $f_2 = 8\,970, \ldots, f_7 = 575$ lb. per sq. in.

As the weight of the heel-slab must be carried by the rods, the areas and spacing of the vertical rods were designed to carry their proportionate part of the weight of the heel-slab. The stresses corresponding are found to be in excess of those due to the moment, M. This excess is taken up by the bond stress in a short distance above $N\ B$, so that above a certain level, only the moment stress corresponding to that level is carried by the vertical rods.

The total stress in the inclined rods, $f_1\ A_1 = 11\,500 \times 9.45 = 108\,675$ lb., is, of course, less than the stress, 127 000 lb., found by ignoring the influence of the vertical rods. This last stress is most easily found by use of the diagram, Fig. 6, and Equation 11, given later.

This example of the counterfort has been given more for the purpose of gaining an idea of the actual stresses involved than of urging the adoption of the more refined method in practice.

If the diameter of a bar is to be some multiple of ⅛ in., there may be no saving by the use of the more exact method. It must be remembered, too, that the vertical bars are not always bonded securely in the base-slab, the earth thrust may also be much increased in times

of heavy rains, where the filling is not adequately drained; and, further, the foundation may be more yielding than estimated.

In the next example, Fig. 4, representing the heel of a T-wall with a fillet, the wall being on the point of overturning, the exact method seems advisable.

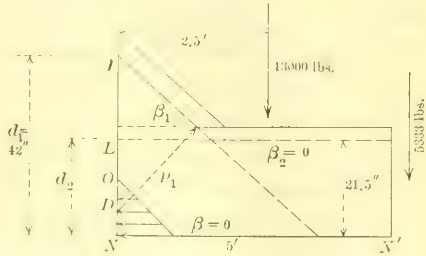

FIG. 4.

The total moment at the section, $N\ I$, due to the two forces shown, is

$$M = (13\,000 \times 2.5 + 5\,333 \times 5)\ 12 = 709\,992 \text{ in-lb.}$$

The reinforcement, shown by the broken lines, for both inclined and horizontal bars, consists of $\frac{7}{8}$-in. square bars, 8 in. from center to center, corresponding to $A_1 = A_2 = 1.15$ sq. in. for a breadth of $b = 12$ in.

Assuming $n = 15$, $\beta_1 = 43°\ 10'$, $\beta = \beta_2 = 0$, $d_1 = 42$, $d_2 = 21.5$, and substituting in Equation 3,

$$\frac{1}{2}\, b\, d_1^2\, k^2 + n\, A_1\, d_2\, (\cos.\ \beta_1 + 1) k = n\, A_1 (d_1 \cos.\ \beta_1 + d_2)$$

we find, after solution,

$$k = 0.238\ ;\ \text{therefore } j = 1 - \frac{1}{3} k = 0.921,$$

$$N\ O = k\ d_1 = 10 \text{ in.},\ D\ I = j\ d_1 = 39 \text{ in.},\ N\ D = 3.33 \text{ in.},$$

$$r_1 = d_1 - kd_1 = 32,\ r_2 = d_2 - kd_1 = 11.5\ ;\ \text{therefore } \frac{r_2}{r_1} = 0.361.$$

By Equation 7, $M_s = f_1\ A_1 \left(p_1 + \frac{r_2}{r_1}\ p_2\right)$, $p_1 = D\ I\ \cos.\ \beta_1$

$$= 28.4,\ p_2 = 18.2\ ;$$

$$\text{therefore } M = 710\,000 = 1.15\ (18.2 + 6.57)\ f_1 = 40\ f_1\ ;$$

therefore $f_1 = 17\,750$ lb. per sq. in., $f_2 = \frac{r_2}{r_1}\ f_1 = 6\,380$ lb. per sq. in.

Where the foundation is good, there can be only a very small moving over of the wall, so that the friction force, 5 333 lb., at N' can be neglected and the soil reaction included. In this particular example (not given in full here) the new values of f_1 and f_2, thus found, are only four-tenths of those given previously.

Special Case. Where $\beta = 0$ and All the Rods Lie in One Plane Which Meets the Section, I N, in a Line at I.—Fig. 5.—The rectangular section has the breadth, b, and, as before, A_1 represents the combined area of a right section of all the rods at I in the breadth, b. To agree with the usual notation, put $d_1 = d$ and $f_1 = f_s =$ the unit stress in the rods. Equation 3 now reduces to

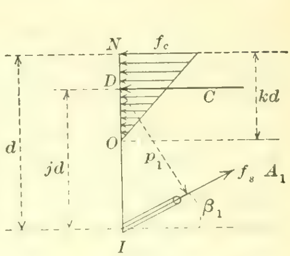

FIG. 5.

$$\frac{1}{2} b\, d^2\, k^2 + nd\, A_1 \cos.\, \beta_1\, k - nd\, A_1 \cos.\, \beta_1 = 0.$$

$$\text{Placing } p = \frac{\text{steel area}}{\text{concrete area}} = \frac{A_1}{b\,d}, \text{ and dividing by } \frac{1}{2}\, b d^2,$$

$$k^2 + 2\, n\, p \cos.\, \beta_1\, k - 2\, n\, p \cos.\, \beta_1 = 0,$$

$$\text{therefore } k = -\, n\, p \cos.\, \beta_1 + \sqrt{(n\, p \cos.\, \beta_1)^2 + 2\, (n\, p \cos.\, \beta_1)} \quad \ldots (9)$$

when $\beta_1 = 0$, this reduces to the usual formula for prismatic beams,

$$k = -\, n\, p + \sqrt{(n\, p)^2 + 2\, (n\, p)} \quad \ldots\ldots\ldots\ldots (10)$$

In Fig. 6, the values of k and $j = 1 - \frac{1}{3} k$, are given as ordinates to the dotted curves for various percentages of steel and values of β_1, varying from 0° to 40°, assuming $n = 15$.

The resisting moment of the steel is found by taking moments about D,

$$M_s = f_s\, A_1 \cos.\, \beta_1\, j\, d = f_s\, A_1\, p_1 \quad \ldots\ldots\ldots\ldots (11)$$

where $p_1 =$ the perpendicular distance from D on the bar.

The resisting moment of the concrete is found by taking moments about I,

$$M_c = \frac{1}{2} f_c\, b\, k\, d\, j\, d = \frac{1}{2} f_c\, (k\, j)\, b\, d^2 \quad \ldots\ldots\ldots\ldots (12)$$

For assigned maximum working values of f_s *and* f_c, the least resisting moment is equated to the moment of the external forces.

In using Fig. 6, note that p is not the percentage of steel, but $\frac{1}{100}$ of the percentage.

Resuming the example of the counterfort, Fig. 3, what will be the result of ignoring the vertical rods? With $A_1 = 9.45$ sq. in. and as

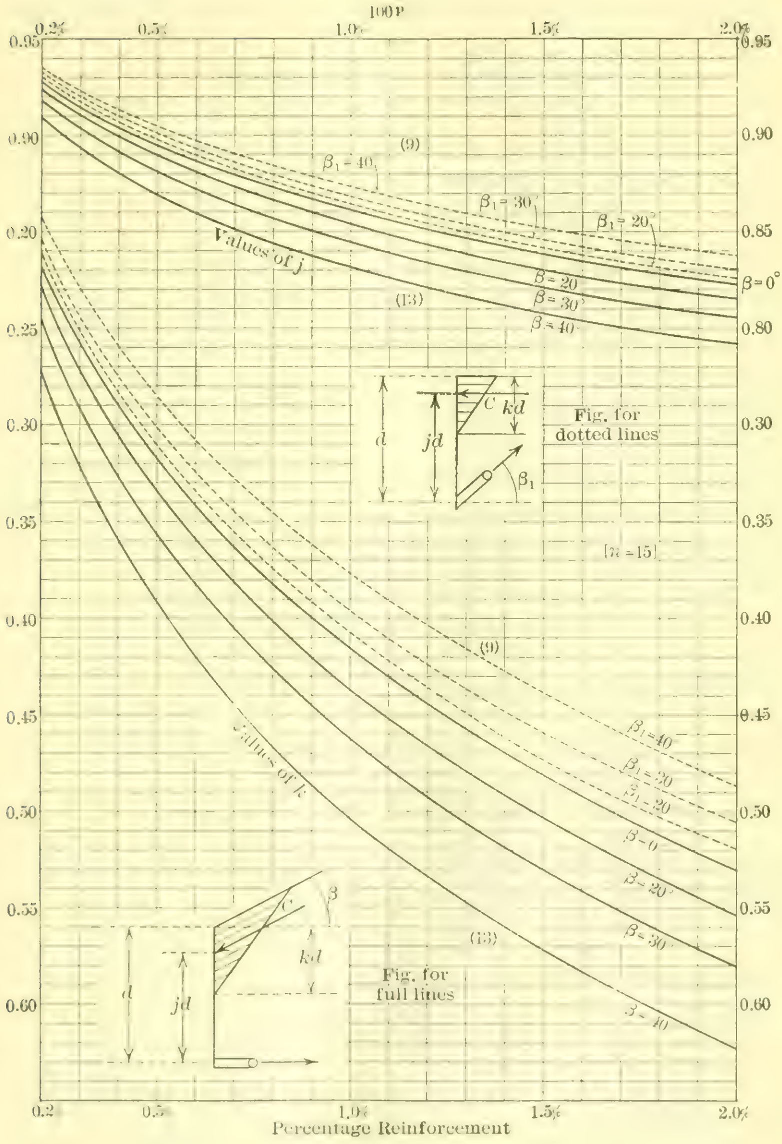
100 P
Values of j
Values of k
Fig. for dotted lines
Fig. for full lines
[n = 15]
Percentage Reinforcement

FIG. 6.

the area of the base or section, $N\ B = 128 \times 18 = 2\,304$ sq. in., $p = \frac{9.45}{2\,304} = 0.004$, or the steel percentage is 0.4. Using Fig. 6, with $\beta_1 = 24°$ and the steel percentage 0.4,

$$j = 0.906;\ \text{therefore}\ jd = 0.906 \times 128 = 116.$$

Hence, as the moment of the earth thrust was given as $M = 13\,454\,100$ in-lb., by Equation 11,

$$f_s\ A_1 \times 116 \times 0.914 = 13\,454\,100;$$

therefore $f_s\ A_1$ = the stress in the inclined rods = 127 000 lb. With $A_1 = 9.45$, as assumed, $f_s = 13\,400$ lb. per sq. in., in place of 11 500 lb. per sq. in., found before, the vertical rods being included.

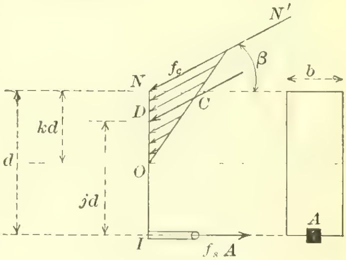

FIG. 7.

Special Case.—Where the Rods Lie in One Plane, for Which $\beta_1 = 0$, But β is Not Zero.—Fig. 7.—Putting d for d_1, and A for A_1, Equation 3 reduces to

$$\cos.^2\ \beta\ bd\ k^2 + 2\ n\ A\ k - 2\ n\ A = 0.$$

Therefore, as before, putting $p = \frac{A}{b\ d}$,

$$k = \frac{1}{\cos.^2\ \beta}\left[-(n\ p) + \sqrt{(n\ p)^2 + 2\ (n\ p)\cos.^2\ \beta}\right] \ldots\ldots (13)$$

In Fig. 6, the full lines give the values of k and $j = 1 - \frac{1}{3}\ k$, corresponding to $n = 15$ and to various values of β and percentages of steel. Equation 7, in this case, reduces to

$$M_s = f_s\ A\ jd \ldots\ldots\ldots\ldots (14)$$

Also, as $D\ G = D\ I = jd$, Equation 8 becomes

$$M_c = \frac{1}{2}\ f_c\ (k\ j)\ bd^2 \cos.^2\ \beta \ldots\ldots\ldots\ldots (15)$$

If, in Fig. 7, we write $p' = d \cos.\ \beta$ = the perpendicular from I on $N\ N'$ produced,

$$M_c = \frac{1}{2}\ f_c\ (k\ j)\ b\ p'^2 \ldots\ldots\ldots\ldots (16)$$

The product, kj, varies with β. In Table 1 the values of $(kj)\cos.^2\beta$, are given for various values of p and β. The values for $\beta = 0$, pertain to a prismatic beam.

TABLE 1.—VALUES OF $(k\ j)\cos.^2\beta$.

$100\,p$	0.2	0.6	1.0	1.6	2.0
$\beta = 0$	0.200	0.303	0.359	0.411	0.441
$\beta = 10°$	0.199	0.299	0.352	0.403	0.427
$\beta = 20°$	0.186	0.281	0.329	0.376	0.397
$\beta = 30°$	0.169	0.251	0.294	0.333	0.351
$\beta = 40°$	0.145	0.212	0.246	0.276	0.289

It is seen from the tabular values and Equation 15, that M_c as given by Equation 15 is always less for $\beta > 0$ than for $\beta = 0$.

In the ordinary theory, given in textbooks on "strength of materials", for homogeneous "beams of equal strength" with variable depth, vertically loaded, it is assumed that at any vertical section the theory for a prismatic beam applies; which entails the postulate that the bending stress at any point of the section acts perpendicular to it. The theory is thus inadequate to express the facts, because it was shown, in the beginning of this paper, that the stress at N, Fig. 7, acts parallel to the face, $N\ N'$.

This common theory, if extended to reinforced beams of the type shown by Fig. 1, is on the side of danger, for it would give, for any β, the value of M_c from Equation 15 corresponding to $\beta = 0$. As a matter of fact, the compressive stresses, Fig. 7, act parallel to $N\ N'$ only at N, and gradually take a less inclination to the normal to $I\ N$, as points are taken farther down the joint. Thus M_c, as given by Equation 15 for $\beta > 0$, is less than the true value, and is thus on the side of safety. The true value lies between that given by Equation 15 for the assumed value of β, supposed to be greater than zero, and the value for $\beta = 0$, doubtless lying much nearer the former value than the latter because M_c is affected to a greater extent by the larger stresses near N, which are nearly parallel to $N\ N'$ and have longer arms, than by those smaller stresses nearer the neutral axis, with their shorter arms.

The case where $\beta = 0$, $\beta_1 = 0$, leads to the ordinary formulas for a prismatic reinforced beam, for which a valuable working diagram was first given* by Arthur W. French, M. Am. Soc. C. E.

* *Transactions*, Am. Soc. C. E., Vol. LVI, 1906, p. 362.

Maximum Shearing Stresses.—Let $I\ N\ N'\ I'$, Fig. 8, represent a part of the beam lying between two sections, $I\ N$, $I'\ N'$, perpendicular to the plane of the paper and parallel to the direction of the loads, and dx apart. These sections are rectangular, having the breadth b. The beam is supposed to be reinforced with the rods $I\ I'$, $L\ L'$, $S\ S'$, . . .

Let V and V' denote the shears due to the loading C and C', the resultants of the compressive stresses, and T and T', the resultants of the tensions in the bars, at the sections, $I\ N$, $I'\ N'$, respectively.

The part of the beam, $I\ N\ N'\ I'$, is in equilibrium under the action of these forces, with the directions given by the arrows, its own weight and load; but as the weight and load are equal to an expression that contains dx as a factor, it is infinitesimal, compared with the forces, and is neglected. It is to be observed, also, that T' is supposed to act in the same line as T, because it approaches this position indefinitely as dx tends toward zero.

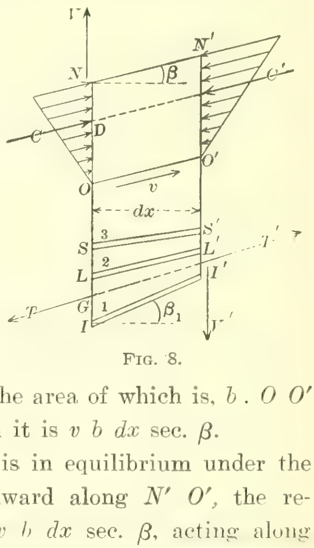

Fig. 8.

Suppose that T meets the section, $I\ N$, at G, and takes moments about G of the forces in equilibrium:

$$(C' - C) \cos. \beta\ \overline{D\ G} = V'\ dx.$$

Taking the neutral surface as parallel to the surface, $N\ N'$, and calling v the unit shear along this neutral surface, the area of which is, $b\ .\ O\ O' = b\ dx \sec. \beta$, the total shearing stress on it is $v\ b\ dx \sec. \beta$.

The prism, $N\ O\ O'\ N'$, of breadth, b, is in equilibrium under the shears, acting upward along $O\ N$, downward along $N'\ O'$, the resultants, C, C', and the shearing stress, $v\ b\ dx \sec. \beta$, acting along $O\ O'$. Hence the algebraic sum of the horizontal components is zero. Therefore,

$$(C' - C) \cos. \beta = (v\ b\ dx \sec. \beta) \cos. \beta = v\ b\ dx.$$

Substituting this value in the preceding equation, dividing by dx, and then taking the limit, as dx approaches zero and V' approaches V indefinitely, it is found that

$$v = \frac{V}{b\ \overline{D\ G}} \qquad \text{.........................(17)}$$

The point, G, can be found without knowing the stresses in the bars, as explained previously. This unit shear, v, exists from the neutral surface to the bars nearest to it.

The case most frequently met is where all the steel reinforcement is placed in the plane through $I\ I'$, perpendicular to the plane of the paper. For this case, G coincides with I and $D\ G = j\ .\ I\ N = jd$, putting $I\ N = d$. Therefore,

$$v = \frac{V}{jd\ .\ b} \qquad \text{(18)}$$

From Fig. 6, j can be found when either β or β_1 is zero, or when both are zero. In the latter case, Equation 18 is a well-known formula, and for approximate values, $j = \frac{7}{8} = 0.875$ is often used.

The maximum shearing stress given by the last equation remains the same for points between the neutral surface and the steel. Above the neutral surface, it decreases, by the usual parabolic law, to zero at N. The unit shear, v, acts parallel to $N\ N'$.

Bond Stress.—In Fig. 8, first suppose the steel bars to lie only in the plane, $I\ I'$. For the breadth, b, let the total tension in the bars at I be t_1, acting in the direction $I'\ I$, and the corresponding tension at I' be t_1', acting in the direction $I\ I'$. The increment of stress $(t_1' - t_1)$, is transmitted by the bond between the concrete and the steel.

Let u = this bond stress per square inch of surface of the rods;
o = the surface area of one bar for 1 in. of length (equal to the perimeter);
$\Sigma\ o$ = the surface area of all the bars in the width, b, for 1 in. of length.

In the length, $I\ I' = dx$ sec. β_1, the total area is $I\ I'\ \Sigma\ o$, and the total bond stress is $u\ dx$ sec. $\beta_1\ \Sigma\ o = t_1' - t$.

Taking moments about D, of the forces, V, V', C, C', t_1, t_1', in equilibrium,

$$(t_1' - t) \text{ cos. } \beta_1\ I\ D = u\ dx\ \Sigma\ o\ I\ D = V'\ dx.$$

Dividing by dx, taking limits as dx approaches zero, and replacing $I\ D$ by $j\ d$,

$$u = \frac{V}{j\ d\ \Sigma\ o} \qquad \text{(19)}$$

In this formula, $d = N\,I$, and j is to be found by the diagram, Fig. 6, or by previous methods. When $\beta_1 = 0$, $\beta = 0$; the approximate value, $\frac{7}{8}$, is often used.

The formulas for both shear and bond stresses, Equations 18 and 19, are of the usual form, corresponding to $\beta_1 = \beta = 0$. They are more general than for the latter case, and it is only necessary to substitute the proper value of j for the values of β and β_1 assumed to obtain the proper values of the stresses.

Where there are several layers of bars, as at $I\,I'$, $L\,L'$, $S\,S'$, . . ., let u_1, u_2, . . ., indicate the unit bond stresses and $\Sigma\, o_1$, $\Sigma\, o_2$, . . ., the areas per linear inch of surface of the rods, for the width, b, for the respective bars; then the total bond stresses at $I\,I'$, $L\,L'$, . . ., are

$$u_1\, I\,I'\, \Sigma\, o_1,\; u_2\, L\,L'\, \Sigma\, o_2,\; . \; . \; .,$$

which are equal, respectively, to $(t_1' - t_1)$, $(t_2' - t_2)$, . . ., the subscripts referring to bars 1, 2, . . ., at $I\,I'$, $L\,L'$, ...

Taking moments about D and proceeding as before, we easily derive,

$$\overline{I\,D}\, u_1\, \Sigma\, o_1 + \overline{L\,D}\, u_2\, \Sigma\, o_2 + \overline{S\,D}\, u_3\, \Sigma\, o_3 + \;.\;.\;. = V.$$

Now, the unit bond stress in any rod is proportional to the unit elongation of the rod, or to its unit stress, which varies with the distance from O [See Equation 6]; hence, for the same loading,

$$u_2 = u_1 \frac{O\,L}{O\,I},\; u_3 = u_1 \frac{O\,S}{O\,I},\; . \; . \; . \qquad \text{(20)}$$

Therefore the previous equation reduces to

$$u_1 \left[I\,D\, \Sigma\, o_1 + L\,D \frac{O\,L}{O\,I} \Sigma\, o_2 + S\,D \frac{O\,S}{O\,I} \Sigma\, o_3 + \;.\;.\;. \right] = V \;..\; \text{(21)}$$

From this equation, u_1 is found; then, from Equation 20, u_2, u_3, . . .

If the interior bars are ignored, and u_1 is found from the simple formula, Equation 19, to be within safe limits, it follows that the true bond stresses on all the bars are less, and are therefore within safe limits.

The application of Equations 18 and 19 is obvious. As Equations 17 and 21 are unusual forms, it may prove of service to the computer to give a numerical illustration. Let it be proposed, therefore, to find

the shear and bond stresses for the heel-slab with the fillet, Fig. 4, already considered.

The total shear at $N\ I$, for $b = 12$ in. length of wall, is $V = 18\,333$ lb. The tension in the bar which makes the angle, $\beta_1 = 43°\ 10'$, with the horizontal, is $f_1\ A_1$, and that in the horizontal bar is $f_1 \dfrac{O\ L}{O\ I} A_2 = f_1 \dfrac{11.5}{32} A_2 = 0.361\ f_1\ A_2$. As $A_1 = A_2$, these tensions are in the ratio, $1 : 0.361$, and the point, G, where the resultant of the two tensions cuts $N\ I$, is the same as for two forces of magnitudes 1 and 0.361, having the same positions and directions.

Let $H =$ the sum of the horizontal components of the two forces supposed. Therefore

$$H = 1 \times \cos.\ \beta_1 + 0.361 = 1.090.$$

Taking moments about D,

$$\begin{aligned} H\ .\ \overline{D\ G} &= 1 \times \cos.\ \beta_1 \times D\ I + 0.361 \times D\ L \\ &= 0.729 \times 39 + 0.361 \times 18.2 = 34.97. \end{aligned}$$

Therefore, $D\ G = 32.1$ in., and the maximum shear is

$$v = \frac{V}{b\ .\ \overline{D\ G}} = \frac{18\,333}{12 \times 32.1} = 47.6 \text{ lb. per sq. in.}$$

Both the inclined and horizontal reinforcement consists of ⅞-in. square rods, spaced 8 in. from center to center. Therefore,

$$\Sigma\ o_1 = \Sigma\ o_2 = \frac{12}{8}\ (3.5) = 5.25 \text{ for } b = 12 \text{ in.}$$

Also, from previous computations,

$$I\ D = 39,\ L\ D = 18.2,\ O\ L = 11.5,\ O\ I = 32 \text{ in.}$$

Therefore, by Equation 21, the unit bond stress, u_1, on the inclined rods is given by

$$u_1 \times 5.25 \left[39 + \frac{11.5 \times 18.2}{32} \right] = 18\,333.$$

Therefore, $u_1 = 76.7$ lb. per sq. in., and the unit bond stress on the horizontal rods is

$$u_2 = \frac{O\ L}{O\ I}\ u_1 = \frac{11.5}{32} \times 76.7 = 27.5 \text{ lb. per sq. in.}$$

In what precedes, there is much that may appear novel. The problems that occur in practice pertain to two different classes of beams.

In those of the first class, illustrated by Figs. 3 and 4, the section, $I\,N$, is taken perpendicular to the face on the compressive side, and the bending stresses there act perpendicularly to the section, as in the ordinary theory. In beams of the second class, as in Fig. 1, the section, $I\,N$, is not perpendicular to the face on the compressive side, and the compressive stresses are all assumed to act parallel to the face. It is possible that this assumption, alone, will be open to criticism, for, accepting the hypothesis, all the results follow readily from simple mechanical laws.

The writer invites a careful criticism of this hypothesis, with the accompanying deductions. A strict solution of beams of the second class is doubtless impracticable, but the writer believes that he has effected a practical solution which is on the side of safety and may commend itself to the practitioner.

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COLORADO RIVER SIPHON.
Discussion.*

By George Schobinger, Assoc. M. Am. Soc. C. E.†

George Schobinger, Assoc. M. Am. Soc. C. E. (by letter).—The danger of the siphon silting up is hardly as imminent as Mr. Cory fears. Although it was operated throughout the irrigation season of 1912 with a flow rarely exceeding more than 300 sec-ft., no diminution in efficiency was noted. During the season of 1913 the flow has sometimes been as high as 600 sec-ft. with similarly satisfactory results. Mr. Schobinger.

Fig. 10 shows the rating curve for present operating conditions. As noted thereon, the head available may vary under ordinary circumstances from 1.8 to 2.2 ft. The loss of head at the gate opening in the shafts and in the tunnel has not been segregated; as the flow increases beyond the limits shown, the effects of these various influences will no doubt be apparent on the curve.

The silting conditions in the distribution system of Imperial Valley, which heads directly in the Colorado River, are, of course, radically different from those on the Yuma Project, where the sluiceway settling basin of Laguna Dam serves efficiently to eliminate much of the silt and heavier sands, a result which was anticipated in the design of the dam. The results of a series of tests conducted by the writer indicate that from 30 to 60% of the silt carried by the river is dropped before the water enters the canal, and that more than 95% of the silt in the canal water below the head-gates is still in the water after it has flowed through 15 miles of canal at low velocity and through the Colorado River Siphon. The velocity in the Arizona shaft is three times as great as that in the sluiceway at Laguna Dam, and

* Continued from August, 1913, *Proceedings*.

† Author's closure.

Mr. Schobinger. therefore it is perfectly evident that a large proportion of the silt which might be deposited at these low velocities has been taken out.

However, even if these conditions were not so, and the unexpurgated waters of the Colorado flowed through the siphon, the writer is of the opinion that the method of operation would obviate any serious inconvenience. At the end of each week the water is shut off at the head-gates, and the canals are allowed to drain. When the water is again turned in, the head available to push it through the siphon may be as much as 9 ft., and this would effectually flush out any light deposit of the previous week.

The writer has recently taken soundings which indicate that there need be no apprehension as to the loss of usefulness of this structure due to silting.

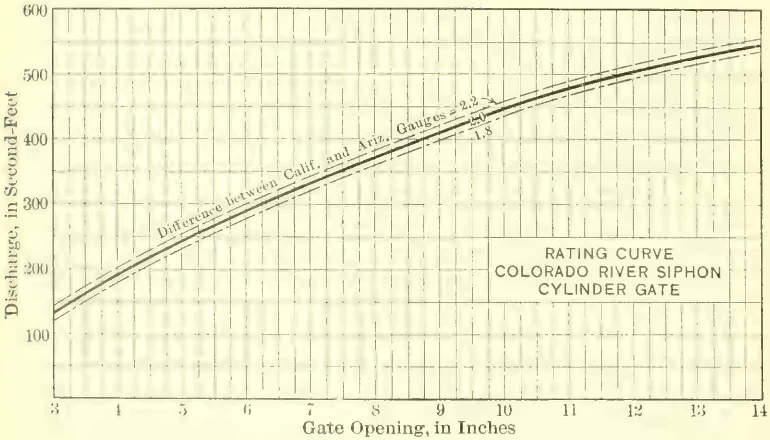

FIG. 10.

It is doubtful whether a general article on the Yuma Project will be written in the immediate future. Laguna Dam, both in design and construction, has been described very completely by E. D. Vincent, M. Am. Soc. C. E., Resident Engineer,* and the levee work and bank protection by Mr. Sellew.† The Colorado River Siphon has been covered in the present paper, and in an article by Mr. Sellew.‡ Until the remaining important features on the Project are under way, it is not probable that a general article on the subject will be forthcoming.

The writer regrets that there has been no discussion on this paper by engineers familiar with pneumatic tunnel work.

* *Engineering News*, Feb. 27th, 1908, Feb. 9th, 1905, and June 10th, 1910.

† *Engineering News*, Feb. 15th, 1912; *Transactions*, Am. Soc. C. E., Vol. LXXVI, p. 1482.

‡ *Engineering News*, August 29th, 1912.

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MODERN PIER CONSTRUCTION IN NEW YORK HARBOR.

Discussion.*

By R. T. Betts, M. Am. Soc. C. E.

R. T. Betts, M. Am. Soc. C. E.—In the type of pier for single-story sheds, developed and built successfully by the Department of Docks under Mr. Staniford's direction, concrete is used for the deck only. Therefore, there can be no question about its durability, as far as exposure to sea water is concerned. In the type of pier for two-story sheds, pedestals of mass concrete, deposited *in situ* on a pile and timber foundation, will support the shed columns. With regard to the durability and permanency of Portland cement concrete exposed to the action of sea water, to which Mr. Harris has referred, the speaker would be inclined to condemn the use of concrete for such exposure, if the experience of the Department of Docks had been as unfortunate as that of the Government, as exemplified by the sea-wall at the New York Navy Yard, and elsewhere. Mr. Betts.

Since the establishment of the Department in 1871, Portland cement concrete has been used in block form and in mass, in the construction of the bulkhead or sea-wall. For the most part the wall built along the shores of Manhattan Island consists of large concrete blocks made in the proportion of 1 part cement, 2 parts sand, and 5 parts 2½-in. broken stone, by volume, and reaching on the face of the wall, from a prepared foundation of concrete in bags on rock bottom at a depth of from 15 to 40 ft. below mean low water, or from a pile foundation sawed to a grade of about 15 ft. below mean low water, up to about 2½ ft. below mean low water, the remainder of the

* Continued from October, 1913, *Proceedings*.

Mr. Betts. face, up to the street grade, consisting, usually, of granite backed with concrete. In the fabrication of these concrete base blocks no attempt whatever was made to produce a dense face, except the usual "spading" along the form. They were allowed to harden thoroughly in air, and their use has resulted in permanent construction. About 5 or 6 months ago, two of these base blocks were removed from the wall at the foot of East 38th Street, East River, in order to enable the New York Edison Company to place an additional intake tunnel. An examination of these blocks, after a submergence of 10 years, showed perfect surfaces. There can be no doubt as to the permanency of Portland cement concrete when moulded in blocks and allowed to harden in air before being exposed to the action of sea water.

Numerous examples (many of them built by the Department of Docks) of concrete deposited *in situ* and exposed to tidal action, such as concrete walls on rock, concrete walls on pile and timber platforms, concrete walls as facing for timber cribs, and concrete foundations for ferry buildings, exist in and about New York Harbor. A personal examination of many of these structures has shown that in nearly every case where deterioration is found, it has occurred in a zone extending from about mean low water to about mean tide, and, as might be expected, walls exposed to considerable wave action show greater deterioration within this zone. It is also observed that where the precaution has been taken to face up the wall with a richer (1 part cement to 2 parts sand) and denser mixture, from 3 to 6 in. thick (as in the case of the Whale Creek wall, and the Wallabout wall adjacent to the New York Navy Yard), the exposed faces are intact, although it must be stated that the Wallabout wall was not exposed to tidal action until after the concrete had had time to become well hardened.

From the nature and location of the deterioration, there can be but little doubt that it is due in the beginning to a dislodgement of the cement by the action of the water before it has had time to set, and its further progress is due to mechanical action, such as frost, ice, and impact from floating débris, rather than to chemical action. In order to prevent spreading, repairs are made, cheaply, easily, and effectively, by cutting out the affected places to a depth of about 2 in. on a falling tide and replacing them with a mixture of 1 part cement to 2 parts sand.

The speaker has no hesitation in saying that good and permanent mass concrete, exposed to the action of sea water, can be obtained, provided the usual, fundamental precautions for concrete work are observed, as follows:

(A)—Design.—All surfaces of concrete deposited *in situ* and exposed to water should be composed of a dense, rich mixture of 1

part cement to 2 parts sand, from 3 to 6 in. thick, depending on whether or not it is exposed to wave action in addition to frost, ice, and floating débris. All edges should be rounded or beveled. Mr. Betts.

(*B*)—*Proper Materials.—Cement, Sand, Stone, and Water.*—The Department specifications for cement require that it "shall not set within half an hour after being mixed with water and shall set within five hours. * * * The fineness shall be such that the percentage of cement passing through a No. 100 sieve shall not be less than 95%." The tensile strength as developed by briquettes of neat cement should be 500 lb. per sq. in. for 1 day in air and 6 days in water, and 575 lb. per sq. in. for 1 day in air and 27 days in water. For a mixture of 1 part cement to 2 parts standard quartz sand, the values at the before-mentioned times should be 225 and 300 lb. per sq. in., respectively. The cement is subjected to the usual "pat" tests for checking, cracking, distortion, and color.

The sand should be clean and sharp.

The stone should be clean, hard, and durable. Gravel should not be used as a substitute for broken stone, except possibly, in "backing" concrete, where it will not be exposed to tidal action.

The water should be fresh and clean.

(*C*)—*Workmanship.*—All ingredients should be mixed thoroughly so as to form a "wet" mixture, and care should be exercised in depositing it so as to get a uniform distribution of the ingredients, without "pockets." "Facing" should be deposited simultaneously with the "backing" and in such a way as to make the mass monolithic. Concrete, especially the exposed surfaces, should not be deposited in water, but the work should be planned and executed so as to keep the depositing in advance of a rising tide. Forms should be carefully made, preferably of dressed, tongued-and-grooved lumber, treated with crude oil or similar material to prevent adhesion of the concrete, and made tight enough (caulking the joints if necessary) to exclude water from the moulds, especially on a rising tide. They should be designed and braced so as to retain their shape accurately, even should it become necessary to fill a mould rapidly.

All concrete surfaces should be kept wet with fresh water for at least a week, in order to insure the proper initial hardening of the cement.

In hot weather, if exposed to the direct rays of the sun, the work should be covered with tarpaulin or similar covering and kept moist to prevent "drying out."

In freezing weather the concrete materials should be heated, not only for the immediate purpose of mixing, but for keeping the frost out of the materials as well. The water should be kept hot, but not boiling; and all concrete deposited during freezing temperatures

Mr. Betts. should be immediately covered and protected from frost until setting is assured.

Walls of mass concrete, requiring the depositing of concrete under water within forms, should not be attempted, unless the enclosing structure or forms are allowed to remain and become a part of the permanent construction, as it is practically impossible to obtain proper surfaces with concrete thus deposited.

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PHYSICAL VALUATION OF RAILROADS.
Discussion.*

By Messrs. T. Kennard Thomson, Charles S. Churchill, R. D. Coombs, Colin M. Ingersoll, and Arthur M. Waitt.

T. Kennard Thomson, M. Am. Soc. C. E.—The Society, and indeed the whole country, owes Mr. Wilgus a vote of thanks for his very complete and valuable paper. It would be difficult to find a phase of the subject on which he has not touched. Mr. Thomson.

The valuation of railroads is, of course, one of the most far-reaching and important investigations ever undertaken by this or any other Government, and the results obtained by the present Commission will naturally be of inestimable value. It is safe to say, however, that, unless this work is done in harmony with, and with the hearty co-operation of, each railroad, the results will not be worth one-quarter of what they should be.

Although the speaker is a strong believer in the benefits which will accrue from the present Government investigation, he thinks that the ultimate object is the "intrinsic value" of the railroads; that is, the real commercial value—not an artificial assumption.

If desirous of buying anything, one must pay what the seller can be persuaded to take, and he, naturally, will not sell if he thinks he can get a better price elsewhere. A seller likes to think that he is getting back all that was spent on his property plus interest, either simple or compound, but he would probably sell at once for a small fraction of the cost, if satisfied that the proceeds could be invested so as to net him a larger or safer income.

The value of a railroad, like that of any other property, must fluctuate enormously from time to time, due to changed conditions

* Continued from October, 1913, *Proceedings*.

Mr. Thomson.

or changed management; and these fluctuations may have very little relation to the original cost of the property.

In buying a fine diamond, does the purchaser inquire what was spent in mining it? If two young men take the same course at Harvard: one at a cost of a few hundred dollars a year—which he earns as he goes—and the other at a cost of many thousands of dollars, will not the first almost invariably be able to sell his service for a higher rate? If these two boys were to invest the same amount of money in houses, one might build or buy a number of houses which he could sell for a big profit; the other might put all his money in a single house and not be able to sell it for one-quarter of its original cost. Two men might start a grocery business, under exactly the same conditions, but with entirely different results, as all know, and so on *ad infinitum*. Why, then, should a railroad alone be forced to put false or fictitious values on its property—for sale, rate-making, or taxation, etc.—instead of its real value at that time?

Suppose a railroad is only a couple of hundred miles long. It may be in first-class condition in every respect, but if it has not a working arrangement with other roads at each end, whereby it can obtain its share of freight, its earning capacity will not be enough to pay operating expenses; and to-morrow a new manager may "get the business" and pay the stockholders a handsome profit. This has been done over and over again. In one case a young engineer, who saw a western road which was "run down", told the owners what he could do if they paid him a percentage of the profits; his proposition was accepted, and this made him a multi-millionaire. How would any basis of actual cost, or cost of reproduction, be applied to these cases?

Mr. Wilgus very truthfully states that it is impossible to ascertain the real cost of a railroad already built. He also states that it has never been possible to predict the actual cost of a road; "cost of reproduction" would come in the same class.

Among other things which have cost the railroads much and would be hard to find are the items of ballasting mentioned by Mr. Wilgus, who states that 24 in. of ballast are needed. In many cases the depth of the ballast is actually more than 12 ft.

Cost of litigation, and other obstructions by property owners, are enormously expensive, not only directly, but also in the brain energy required to overcome them, which might have been spent on the construction or operation of the road. For instance, the Chesapeake and Ohio Railroad, being unable to obtain from an old Virginian permission to use part of his property, took possession. The owner removed the tracks and buried the corpse of a woman there; the railroad company dug up the body and buried it 150 miles away; the owner found the body, brought it back, and again buried it on the "right of way", this time embedding it in concrete. As the concrete was very hard,

and the railroad company did not like to use dynamite, it simply raised the grade of the track, and allowed the body to remain in peace under the rails. Mr. Thomson.

Without the co-operation of the railroads, an investigator might easily overlook the old New York Central Railroad line through Kingsbridge, New York City, and estimate the Marble Hill cut-off at a fraction of its cost. In the West a railroad tunnel which had been closed three times by land slides was abandoned for a temporary line with a very sharp curve, and years afterward was rebuilt in a different location.

But why continue when every one knows that the exact cost of an old or to-be-built railroad can only be ascertained approximately?

Mr. Crehore's suggestion, that the railroads put a valuation on their own property, has much merit, and reminds one of the method used in Germany for many years, the speaker believes, successfully, whereby the owner of a house gives the valuation of his property, and this is used by the Government for purposes of taxation and fire insurance.

Charles S. Churchill, M. Am. Soc. C. E.—In the speaker's opinion, Mr. Wilgus should be thanked for having brought out his points in a very clear form, these points being recognized as generally correct. Within a few weeks after the issuance of the paper the Government officials made some very important statements: First, that the valuation of properties of common carriers in compliance with the Act, Section 19-a, is an original proposition; second, that it is a continuing one; and, third, that the physical elements must be compiled or estimated in accordance with the Interstate Commerce Rules of Accounts, as stated in the Act. Mr. Churchill.

Under the first statement, that the valuation of properties is an original proposition, it appears probable that no value which has heretofore been made will fully meet the requirements of the Act. Under the second statement, that the requirement is a continuing one, it becomes extremely important that accurate records shall be kept of the cost of all work, in accordance with the Interstate Commerce accounts. This statement also has led to plans being formulated by Government officials for preparing their files to cover 100 years. The third statement, that all records and estimates shall accord with the Interstate Commerce accounts, is one of the most important features of the whole Act, because this simple requirement answers many of the points raised in the written discussions on this subject, especially for the reason that the Interstate Commerce accounts are quite clear. Therefore, it is thought very important that the law should be studied very carefully, as it is a good one in many respects.

Mr. Churchill.

Many progressive railroad properties double themselves within 20 years; therefore, suppose one makes a valuation now, 20 years hence very little trace of the items reviewed at this date will be found, because the properties are changing and building up constantly.

The question has been asked, "What has the public gained in existing railroad properties"? Recently, some records of railroad construction between 1850 and 1856 have been found, which show that a railroad was being built across one of the Colonial States, and that within 6 years—before it was entirely completed—the actual returns in taxable values were doubled in each of the counties through which the railroad passed. This old record shows where both the individual land owner, and also the communities, counties, and State have gained from the fact that certain individuals combined in constructing railroad properties. This is one kind of return out of many others which have come to every community and State in which railroads exist.

Attention is called to the point in the law, that the valuation asked for is not confined altogether to physical features; also, that the law specifically calls for the cost of the property to date; in other words, that the investment in a property must be determined as closely as practicable, as being an important element. If, therefore, a railroad has built a property within recent years, or has bought one at an earlier date, and has made considerable additions thereto since the date of acquirement, the original cost plus the additions must be determined. In most instances records of expenditures have been carefully kept, and usually there are three parties to these records, namely, the railway company, the contractor, and the engineer. The amounts paid, therefore, show on their face the true cost of the work when built.

Finally, attention is called to the recent decision of the Supreme Court in the Minnesota Rate Case, wherein a favorable decision was given in one case, and, in that case, the original investment was protected.

In conclusion, it seems important to draw attention to the greater likelihood of overlooking items of cost after the structure or railroad has been completed than in making proper allowance for contingencies before the work is undertaken; and that these items of cost, which are so likely to be overlooked in works already completed, should be searched for in great detail, so that the application of percentages to cover past contingencies may be avoided as far as possible.

Mr. Coombs.

R. D. Coombs, M. Am. Soc. C. E. (by letter).—It would appear to be necessary to have a more general acceptance of what is meant by "cost" and "value": Whether the "cost" of construction is its actual cost, what it should have cost under actual conditions and average good management, or what it should have cost under average

conditions and average good management; and whether the value new corresponds with any or none of these. Mr. Coombs.

Assuming that the railroad's actual expenditures could be determined, they would in fact represent the cost, whether that cost was unusually low, or unusually high, unless it is accepted that deductions should be made for bad luck, ignorance, or dishonesty.

If it is a fact that, owing to working conditions, weather, accidents, high wages, and relatively expensive material, a certain work cost the railroad an amount greatly in excess of its probable cost under average conditions and efficient management, should the actual cost be accepted as its value new?

If the necessity of maintaining service compels expensive construction, should the excess cost over that of average conditions remain a part of the cost of the work, and would that cost be accepted as the value new?

If the improved methods of construction now available would decrease the cost of new work below the amount actually expended, should such methods be used in estimating the value new?

If the original contour and the topographical conditions along the line are assumed to be restored in the cost of reproduction new, a fair estimate, in some cases at least, would require us to assume the surrounding country restored and to make some allowance for working under such conditions.

Until those discussing this matter agree on the foregoing points, there will naturally be no agreement on further extensions of the subject.

That the actual cost would be difficult to determine does not appeal to the writer as a logical reason for discarding it altogether. In many cases the cost of reproduction new might be used as a "side light" on the actual cost.

It must be admitted, however, that the actual book records are not absolute cost records. In fact, the writer does not believe that the accounts of any railroad, and of but few contractors, would show the complete expenditures for a given construction.

Referring to the acceptance of one basic principle or another, and to the deduction or inclusion of depreciation, depending on the purpose of the valuation, it would appear:

First.—That if the directors have set aside a depreciation fund, that fund plus the physical property represents accurately the full physical value of the property, and may be properly used as the physical value for any purpose.

Second.—If such a fund has not been established, the physical value is represented by the actual physical property, and is less than 100% of its book value.

Mr. Coombs.

Third.—As the present stockholders are not necessarily the original stockholders, some of them, under the last assumption, are innocent purchasers of stock which does not represent full value, in so far as the physical property is concerned.

Fourth.—The physical valuation of a railroad is its valuation as a railroad in its present location, and, from an engineering standpoint, the value should be the same either for sale, taxation, or rate-making.

Fifth.—If taxes are too high or too low, change the percentage; if freight rates are too high or too low, change the rates.

Mr. Ingersoll.

COLIN M. INGERSOLL, M. AM. SOC. C. E. (by letter).—To railroad engineers who have advanced in their profession, and have been through the construction period from beginning to end, this paper will most certainly appeal, for it describes in detail the very steps taken in building a railroad.

As yet, the physical valuation of railroads is in its infancy, and no definite method has been determined for making such valuation; but Mr. Wilgus has done a great service to the Profession in publishing his paper, and this will be proven when the final method of valuation is determined by the Government.

The method to be used in arriving at the valuation depends somewhat on what use is to be made of it. If it is for a quick transfer by sale, it would seem that the property should be turned over on a reproduction value, less depreciation; but if the property is kept up in a substantial manner, it would seem to the writer that the cost of reproduction new is the method which comes nearest of any that has yet been advanced to putting all roads on the same footing. The original-cost-to-date method of valuing would not seem to the writer to be fair for all, for until very recently the railroad companies were rather slack in keeping accurate costs of work. Take a railroad built in the Sixties or Seventies, the books of which have been kept up (and the writer doubts if there are very many such roads); the books would show the money that had been put into the railroad, but without any allowance for the enhanced value of the property. Perhaps the road adjoining has kept no books, and, consequently, in order to arrive at the present value, some method of reproductive value must be used.

In the first instance one cannot, by any arbitrary rule, arrive at the present-day values unless one gets at the cost of reproduction; and if this is done, the original cost is of use as a side light. Then, again, rarely in "original costs" are the whole costs shown. In construction work contractors have often received extra compensation, either by agreement or through legal process, which does not appear

Mr. Ingersoll.

in the book cost of the work. Book costs show the cost of the property, but rarely include all the costs, such as engineering, legal fees, commissioners' fees, interest on money during construction, and operating losses, which really are a part of the cost of the property. In many instances land has been given and contributions have been made, for establishing stations, side-tracks, etc., in order to induce the company to build. It would seem to the writer as if they were just as much a part of the road that should be allowed to earn interest as that which was paid for. It is taxed, and can be sold and credited to the company. In many instances the purchase price of land is more than the value of the adjoining land, and rightly so. Those who have had to do with the purchasing of right of way know that one cannot go diagonally through a piece of farm land, say 5 acres, take out 2 acres, and leave the remainder of the same value per acre. For that very reason an extra price has to be paid, whether it is called an increment, damages, or an inducement to sell. It is there, and is a part of the cost of the property.

If for any reason the records of the purchase of this piece were destroyed, it would not seem to be fair that it should be valued on the basis of the value of the adjoining property. It is true that railroads can condemn, but, with small pieces of land, it is generally cheaper to purchase at a higher price than to go through condemnation proceedings, pay for commissions, lawyers, engineers, and witnesses, which, if the property is not expensive, amounts to a big percentage of the cost. Take the same case of 5 acres of land, at, say, $10 per acre. The owner for some reason, often for gain, refuses to sell. Has it been the experience of any one who has purchased land for right of way that the railroad company can get the 2 acres of land needed for $20 by condemnation? No; the lawyer, the commission, the witnesses, the engineering, etc., would cost more than twice that amount, and some method must be found to include these legitimate expenses in the value of the land. Otherwise, the railroads will have to put in capital on which no return in the way of dividends can be paid. This certainly would not seem to be fair to the investor.

The writer believes that it is proper to charge property with its share of the engineering and legal expenses, and contingencies, for the very good reasons set forth by Mr. Wilgus.

For rate-making purposes it is not believed that depreciation should be deducted from cost of reproduction. Depreciation is an element of operating costs and an obligation of the stockholders.

If a railroad has been allowed to run down while dividends have been paid, then the stockholders should forego dividends, and the earnings should be put into the property until it is brought up to standard.

Mr. Waitt. ARTHUR M. WAITT, ESQ. (by letter).—The writer has read this able paper with great interest, as it is based on large practical experience, and deals in a broad and comprehensive manner with a subject which is of vital importance both to the railroads and the general public.

Probably few, if any, men have given deeper or more conscientious thought to the subject, or have had such an extensive practical experience to enable them to deal with the matter as fairly and comprehensively, as Mr. Wilgus.

It is the writer's firm conviction that in determining the physical value of railroad properties for purposes of rate-making, in justice and equity, only one basis can be used, namely, that which considers the actual capital required to reproduce the conditions and facilities found necessary by the railroads to produce their revenue, and he fully agrees with Mr. Wilgus that for rate-making purposes depreciation should not be deducted.

An intimate relation with the shop equipment and rolling stock of both American and European railroads for a long period has caused the writer to study especially the treatment of these important elements in the total valuation of railroad properties.

Oftentimes, in his practical experience, the question has arisen as to whether comparisons of the values of equipment and rolling stock taken at different periods, several years apart, would show an appreciation or a depreciation. In every instance, a careful analysis of the facts and figures, ignoring new equipment charged to the "improvement" or "capital" accounts, has shown no net appreciation in values, due to the fact that new tools and rolling stock purchased to replace old ones were invariably heavier and more valuable than the worn out or obsolete equipment. It would be true only in a few exceptional cases that, in valuations made 5 years apart, there would be an actual depreciation in total values of unincreased equipment.

If physical depreciation were deducted from cost to reproduce new, figures would be obtained which would not fairly represent the capital involved to provide the facilities and operating conditions on the railroads, for which adequate rates for transportation should be allowed.

A fair valuation of equipment or rolling stock, or, in fact, of any of the elements composing the railroad's total value, cannot be made, except by a reasonable personal examination by qualified experts in the different fields, and it cannot be done equitably by arbitrary or set rules applied regardless of local conditions.

In a valuation of the equipment or rolling stock of a railroad to determine its purchasable value at any given time, different principles would apply, and in such cases the cost of reproduction new, less existing depreciation, would be the correct measure of value. In a valuation for this purpose, no set prices and rules, applicable

to all cases, can be established; the prices and percentages must be established after an examination of a sufficient portion of each class of equipment to enable an expert to determine the comparative initial values and the quality or standard of maintenance, this latter to be used in the case of each class of equipment or rolling stock. Mr. Waitt.

It would be manifestly unfair to value by the same standards and figures the property of two railroads, one of which constantly purchases new locomotives, cars, machinery, and tools of the highest grade, having all the best features for obtaining high efficiency in service and longevity of equipment, and on which, by the wise expenditure of money, the equipment is maintained in the best condition for service, while the other road purchases cheap equipment and expends as little as possible in maintenance. Situations approaching each of these cases will be found, and the writer maintains that they can only be handled equitably by qualified expert judgment after personal inspection.

No more important facts can be urged for consideration and correspondingly wise action than those which are made prominent in Mr. Wilgus' paper, but in closing the writer wishes again to emphasize two of them which, to his mind, are the most important, namely:

1.—The cost of reproduction new without depreciation should be taken as the only fair and true measure of the physical valuation of railroads for purposes of rate regulation.

2.—Expert skill and experience must be enlisted in order to make a proper estimate of the true value of railroad properties.

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FLOOD FLOWS.

Discussion.*

By Messrs. Arthur E. Morgan, H. V. Hinckley, E. F. Chandler, Allen Hazen, and Morris Knowles.

Arthur E. Morgan, M. Am. Soc. C. E. (by letter).—Mr. Fuller's paper suggests several very profitable fields of inquiry, and is sure to stimulate further investigations that will be of definite value. Mr. Morgan.

One of the fundamental assumptions is that weather conditions throughout the United States are not subject to "permanent changes." It is also assumed that climatic conditions which will produce maximum storms do not occur over the country as a whole during any given year, but that storm conditions are more or less local. An examination of the monthly and yearly precipitations at rainfall-recording stations in all parts of the United States seems to indicate the general accuracy of this assumption for the last 100 years. However, certain notable facts stand out which lead one to question its accuracy for the interior part of the United States.

For instance, in 1844, the largest flood ever recorded occurred in the Red River, through Texas and Arkansas, this river having a drainage area of about 50 000 sq. miles. During the same year the greatest flood on record occurred in the Kaw River, at Kansas City, where the drainage area is 35 000 sq. miles, and the same year produced the greatest flood in a century and a quarter on the Mississippi River, at St. Louis, and the greatest floods on record in the Missouri and Illinois Rivers. The areas over which the floods of 1844 were the greatest on record, are comparable to the total area of France and Germany. Again, in 1903, the greatest flood since 1844 occurred in the Kaw River,

* This discussion (of the paper by Weston E. Fuller, M. Am. Soc. C. E., published in May, 1913, *Proceedings*, and presented at the meeting of October 15th, 1913, held in New Orleans, La.), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

Mr. Morgan. at Kansas City, in the Mississippi River, at St. Louis, and in numerous other streams throughout the Central States. As far north as central Minnesota, the heaviest rainfall ever recorded occurred at the same time. Also, in 1903, floods, among the greatest on record for those streams, occurred on the Verde River, in Arizona, the Colorado River, the Raritan and the Delaware, in New Jersey, Cape Fear River, in North Carolina, the Alabama River, in Alabama, the Monongahela River, and on various other streams, from South Carolina to Oregon. Although there is no definite evidence that periods of maximum floods will occur over the entire country at the same time at long intervals, it appears that so little is known about the facts of the case that this assumption is far from being proven for long periods under conditions existing in the central part of the United States. It is possible that certain seasons at long intervals are subject to unusual storm disturbances resulting in floods, though the average yearly or even monthly rainfall may not be above the normal for the country as a whole.

Mr. Fuller assumes that the relation between the average annual flood and the maximum possible flood is the same for largely different sections of the country, and the same for the United States as for Europe. He draws attention to the fact that in the arid regions of the United States rainfall and floods are very erratic, and that, though several years may pass without a flood, very large floods may occur.

Although the data are very meager, the writer believes that the climatic conditions which cause this tendency are not limited to the arid regions, but extend to a greater or less degree over the entire United States between the Appalachian and Rocky Mountains, which is the region in which he is particularly acquainted with flood flows.

For instance, careful calculations of flow on the Miami River, at Dayton, Ohio, have recently been made. A gauging station has been maintained in good order at this point for 20 years. The average annual flood for this period is approximately 32 000 cu. ft. per sec. from an area of about 2 500 sq. miles. According to the formula proposed by Mr. Fuller, the maximum flood for a century should be about 2.9 times the average annual flood, or about 85 000 cu. ft. per sec. According to fairly dependable approximations, this flood flow has been largely exceeded four times in the last 107 years. According to Mr. Fuller's formula, the maximum possible flood in 1 000 years would be about 3.9 times the average annual flood, whereas, according to very careful calculations of flow, it appears that the flood of March, 1913, was about 8 times the average annual flood. It may be that climatic conditions show a greater range of variation west of the Appalachian Mountains than east of that range, or in Europe, from which most of the long-time records referred to by Mr. Fuller were secured.

Another assumption by Mr. Fuller is that the same ratio between average annual floods and maximum possible floods exists for streams, regardless of the size of the drainage area. The writer believes that general experience will fail to uphold this assumption. It is known that small drainage areas are subject to very extreme precipitations, and that the most extreme of these precipitations are always local. Mr. Morgan.

For instance, there is the case of the flood on Devil's Creek, in Iowa, which occurred in 1905. Rough estimates of this flow made by the U. S. Geological Survey* indicate that, from an area of 143 sq. miles, the run-off was about 1 300 sec-ft. per sq. mile. From rainfall records at the surrounding stations it appears that from 10 to 12 in. fell on the water-shed, the greater part of it in 12 hours.

Although little dependence can be placed on such estimates of run-off as are recorded for this flood, the rain which fell was sufficient to produce an average 24-hour run-off of probably not less than 200 sec-ft. per sq. mile, or 8 in. from the entire water-shed. This is in a region where the average annual rainfall is about 35 in. and where the annual average maximum rainfall for 24 hours will not exceed about 2 in., the heavier storms coming during the summer when run-off from small rainfalls is light. It is safe to assume that during the flood of 1905 the maximum 24-hour run-off for this territory was not less than 10 times the average annual flood. This extreme case is given simply to illustrate the fact that the range of flood run-off is far greater for small than for large areas.

Similarly, during the flood of March, 1913, in the Miami Valley, certain tributaries with drainage areas of 50 or 100 sq. miles indicate a maximum run-off of at least 400 sec-ft. per sq. mile, which is probably at least ten times the average annual flood. On large water-sheds of 10 000 sq. miles or more, excessive rainfall in one part of the water-shed is usually balanced by lack of rainfall in another part, and the ratio between the average annual flood and the maximum possible flood must be less than for small areas.

When alluvial streams overflow, sand and silt are deposited along the banks up to within 2 or 3 ft. of the surface of the overflow. Along the lower Mississippi and the Red Rivers, in Texas and Arkansas, and the Arkansas River, in Arkansas, there is no evidence of such silt and sand being deposited at elevations very much above those of recent floods. The conclusion is that during recent centuries there have not been floods in which the stage of water was very much above that of recent ones. The only points at which such comparisons can be made safely are along the abandoned loops and cut-offs in the rivers, where the banks have not caved in. On the contrary, on small streams evidence of very different conditions is found. It is fairly common experience, along streams with water-sheds of from 10 to 500 sq. miles,

* Reported in Water Supply and Irrigation Paper No. 162.

Mr. Morgan.

especially in the northern and mid-western States, to find deposits of gravel very evidently placed by flood-water at elevations very much above the elevation of any recorded flood.

The inference is that all the interior part of the United States is subject to very rare local floods of very great intensity, comparable, perhaps, to the one already referred to on Devil's Creek, and that the run-off of such maximum possible floods may be ten times as great as the average annual flood, instead of three or four times as great, as indicated by Mr. Fuller's formula. The suggestion is that, in determining the relation between average annual floods and the maximum possible flood, the extent of the drainage area is an important factor.

The data do not indicate the extent to which flood records have been examined, in the preparation of the paper, but the flood flows on foreign streams outlined in Table 30 would not, it seems, furnish a reasonable basis for the acceptance of such a formula as suggested. For instance, of the floods for which the date is given, more than one-third occurred in 1887 and more than one-half of them in a period of 7 years.

This paper is valuable in that it suggests pointedly that there is a definite relation between the average annual flood on any stream and the maximum possible flood for that stream, and in suggesting that, to a certain extent, short-time records for many streams will serve the same purpose as long-time records for a single stream.

When one considers the number of assumptions which must be made in the use of the formula for determining the maximum possible flood, it would seem that in some cases it might be better to estimate the maximum possible flood by what might be called the rational method, that is, by determining from the basis of experience and the maximum rainfall to be expected, the relation of rainfall to run-off under the conditions which would exist in an assumed case, considering the elements of topography, shape of the drainage basin, direction of storms, season of the year, etc.

There is just one other point that should be mentioned. Mr. Fuller states very clearly that there are two kinds of variables to be met in flood flow: one class varies with different rivers, and includes topography, soil conditions, etc.; the other class of variables, including possibilities of rainfall, weather, temperature, etc., may be alike for many streams, but vary as to time. A statement has been made by the author, which does not appear in the paper; this indicates to the writer the value of his work, but also possibly, the danger of feeling too secure by an improper placing of the burden of those two elements. For instance, if we use his formula, we must assume a value for C, that is, a value representing the variable conditions with regard to watersheds, etc. If C is made to fit the case, the formula can be made to fit any particular river or flood, but unless we know how that factor,

C, was determined, we do not know whether the formula fits any particular case accidentally, or whether C has been determined properly. Mr. Fuller has mentioned one particular river in which he assumed the coefficient, C, to be 100, that is the Miami above Dayton, Ohio. The difference in elevation there between the top of the water-shed and the river valley is seldom more than 200 ft., as compared with mountain streams where the variation may be 1 000 ft.; and the soil formation is variable, being gravelly in some cases. At the time of examining this paper, the writer discussed it with other engineers in his office and came to the conclusion that one could not assume for that valley any higher factor for C than 50. The point is, that in plotting various storms, unless the engineer is thoroughly familiar with the variable factor, C, on one water-shed, as compared with the value of that factor on other water-sheds, he does not know the extent to which the intensity of flood flow is determined by the variable, C, which is constant for that water-shed, and to what extent it is determined by the time variable, including rainfall, season, temperature, etc. Mr. Morgan.

H. V. Hinckley, M. Am. Soc. C. E. (by letter).—In addressing the Oklahoma Engineering Society, on December 27th, 1911, the writer said: Mr. Hinckley

"Some of us are perhaps not aware that a 20 or 30-year record of high water, minimum or maximum flow, or rainfall, may often be of comparatively little value. It seems to be a fairly well established rule that it takes fully 50 years to complete an engineering meteorological cycle. This was illustrated, for example, at Topeka, Kans. When the Melan Bridge was built over the Kansas River in 1897, the City Engineer's records for 25 years showed a maximum rise of 15 ft. from L. W. to H. W., and the oldest inhabitant, who claimed that he had seen the river go clear out of its banks and flood the entire valley prior to 1850, was deemed to be in his dotage and untrustworthy. In 1903, however, the recorded variation of 15 ft. between low and high water was changed to 28 ft.; asphalt pavements were 6 ft. under water; the oldest inhabitant was vindicated, and the river proved what every one should have known—that the high-water mark, in an alluvial valley which has been built up by sediment dropped by the floods, is necessarily higher than the ground surface of the valley—regardless of the records of the City Engineer's office."

While these remarks bear out, in a general way, the author's conclusions, the writer acknowledges that his 50-year "meteorological cycle" is subject to amendment.

Tables 1 and 2 give, at a glance, an idea of what may be reasonably expected, and, from this time forward, the Profession will be able to act more intelligently in the design of waterways and storage reservoirs. The writer has been collecting data in regard to maximum rainfall for 30 years, and the two subjects together are an interesting study.

Mr. Buckley. There are plenty of bridges and spillways which may stand up under 1.80 times the annual flood, but will go out when 3.40 times the annual flood comes.

The author has given us a valuable paper which has propounded to every hydraulic engineer the question: "For how many years will your works stand?"

Mr. Chandler. E. F. Chandler, Assoc. M. Am. Soc. C. E. (by letter).—The newly deduced record of the Red River of the North, at Grand Forks, N. Dak., furnishes an interesting illustration of the principles concerning flood flows enunciated so clearly by Mr. Fuller, and also shows the modifications which may result from local conditions.

For 12 years the U. S. Geological Survey has maintained records of this stream; in addition to these, the writer obtained copies of an accurate gauge-height record which had been maintained for 19 years previous, and of a few discharge measurements made in those early years. From these data, he was able to develop a fairly good, complete record of the discharge for the long period of 31 years, 1882 to 1912. Only nine of the records included in Mr. Fuller's paper cover so long a period.

For comparison, the records of the two principal tributary inflowing streams, the Red River, at Fargo, N. Dak., and the Red Lake River, at Crookston, Minn. (which have been observed for 11 and 10 years, respectively), may be considered at the same time. The complete records to date for these stations are shown in Table 31, and might be included in Table 18.

TABLE 31.—Values for Coefficient, C, in Formula $Q = CA^{0.8}(1 + 0.8 \log. T)$.

Stream.	Station.	Area, A.	Q (Ave.).	Larger flood, Q.	Period, years, T.	Values of C. From larger Q.	Values of C. From Q (Ave.).
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Red	Grand Forks, N. Dak..	25 000	17 440	42 400	31	5.8	5.3
				40 800		6.5	
				37 500		6.7	
				33 400		6.8	
				32 920		7.0	
Red	Fargo, N. Dak.........	6 020	2 809	6 090	11	3.1	2.6
				5 800		3.5	
				4 250		3.5	
Red Lake.	Crookston, Minn......	5 320	7 473	14 200	10	8.3	7.8
				13 600		9.3	
				10 300		9.3	

The largest floods did not occur in the same years at these stations, notwithstanding the fact that the latter two are tributary to the first; therefore, all three records may be considered. Mr. Chandler.

In each case, the largest flood was less than that which would be given by the logarithmic formula, on the basis of the median floods. It seems that this might reasonably have been expected from the topographic characteristics of the Red River Valley, the river and all its main tributaries flowing through remarkably level prairies, usually in channels only a few hundred feet wide and from 10 to 40 ft. below the prairie level. On each side the prairie is almost as smooth as a floor, and the rise away from the river bank is only a few feet per mile. The capacity of the channel is sufficient to carry ordinary floods, but the largest floods, which occur only once or twice in a decade, overflow the prairie in shallow sheets; thus the regimen of the stream is changed essentially during the extremes of such floods, the rate of flow much retarded, the time of high stage increased, and the extreme maximum correspondingly diminished.

Another peculiarity which appears in the tables for this region, and perhaps might have been predicted from the topographic and meteorologic conditions, is the smaller value obtained for C in Column 8 (from the flood average of all years) than in Column 7 (from the largest floods). The Red River Valley is near the "semi-arid" region, and the river separates a prairie State from one largely forested. At one margin of the drainage area, the mean annual rainfall is about 16 in., at the other margin 24 in.; the long-period mean annual run-off is about 1 in. at one side and 4 in. at the other. Therefore, in a region where evaporation consumes almost the whole of the precipitation, and the run-off is so small a remainder, after any season of deficient rainfall, the run-off becomes much less even than the normal, and then remains comparatively steady until the ground storage is replenished by surplus rainfall, and at such times it is little affected by ordinary rainstorms. Thus, though the greatest recorded flow at each of these stations is ten or twelve times the long-period mean run-off, there are many years when there is no noticeable flood, and three or four years out of every ten when the largest flood of the year is less than three times the mean discharge. As a result, Q (Ave.), the average of the annual floods, gives a smaller coefficient than that obtained from the larger floods individually.

It is probably the same cause, namely, the small maximum discharge of some years, which gives rise to a different logarithmic factor (in a formula deduced only from the streams of this region) than that deduced by Mr. Fuller from the average of streams scattered through the whole country. Instead of the factor, 0.80 log. T, in the formula, $Q = C\ A^{0.8}\ (1 + 0.80 \log. T)$, the largest flood at each of these three stations would give 0.95 log. T, 1.12 log. T, and 0.90 log. T. In this

Mr. Chandler. region, as mentioned previously, the greatest floods do not seem to be as great in comparison with those of secondary magnitude as is normal in other regions; if, therefore, we omit a few of the largest from consideration, the following floods would give factors from 1.10 log. T to 1.30 log. T.

Mr. Fuller states that the rivers of the Hudson Bay drainage varied so widely among themselves that no logarithmic plottings of them were published. The Red River Valley portion of the basin, however, including these three records and numerous other shorter or less accurate records, shows fair uniformity. As Mr. Fuller explains, in some cases local conditions may be expected to modify the application of the formula or to change it to some extent, and such seems to be the case here. The importance of this case would not be great enough to justify this addition to the discussion, were it not for the length of the record—31 years. We see illustrated how useless or erroneous it would be to attempt to deduce figures concerning the flow of an unknown stream where no actual measurements had been made in the region; but, on the other hand, by using the records as a basis for small necessary modifications, the principles enunciated by Mr. Fuller seem, in general, to apply in this region also, and to furnish excellent starting points for more detailed studies.

Mr. Hazen. ALLEN HAZEN, M. AM. SOC. C. E. (by letter).—This is a most important paper, because, as far as the writer knows, it is the first attempt to apply the principles of probabilities to the flood problem.

The writer has followed the author's work in detail, and believes that his methods are sound. As time goes on, data covering longer periods and more streams may change some of the numerical values; but the underlying idea of treating the recurrence of floods as a matter of probabilities, to be determined by an examination of the records of many streams, will stand.

When the writer first took up the study of this problem, several years ago, he believed that it would be safer to use as a basis the records of a few streams which covered long periods, where knowledge of flood flows had been obtained from records of the height of water over the crests of substantial dams above the influence of back-water, and where there could be no question as to the accuracy of the results. On the basis of a limited quantity of selected data, tentative values were reached. The author afterward extended the investigation to include short-term records of many more streams; but the numerical values resulting from this broader study were fully in accord with those first obtained by the writer from the small quantity of selected data.

Taking into account the many elements of error which exist or can be imagined to exist in stream gaugings, and especially the fact that estimates for extreme floods in many or most cases are based

Mr. Hazen.

on extrapolations from rating curves, often at some distance above the highest stage for which gaugings have actually been made, the writer would feel disposed, in case they differed, to attach quite as much importance to the results obtained from his first study. As the more extended studies presented by the author are entirely in accord with the writer's earlier ones, this question does not require discussion, and the writer feels confidence in the general accuracy of the results.

In another paper to be presented to the Society, the writer has described a graphical method of representing data of the same general character as those used by the author, based on the probability curve, or, as it is otherwise called, the normal law of error. A new kind of cross-section paper is made, in which the spacing of the lines in one direction is computed from tables of the probability curve, so that figures representing the summation of that curve plotted on it fall in a straight line.

From a study of the author's data it is clear that the relation between flood flows and the normal law of error is such that this probability paper could have been used for his study, had it been available. Its use might have facilitated some of the work, but there is no reason to think that it would have changed to a significant extent any of his conclusions. In fact, the paper the author has used for his study corresponds so closely with that part of the probability paper in which most of his data would fall, that the differences would not have been important in the graphical method.

The figures for maximum flood flows of the same stream through a series of years clearly bear a relation to the normal law of error, but they do not follow it exactly. When plotted on probability paper they form what is called a skew curve. The variations downward are more numerous than the variations upward, but are smaller in magnitude.

It is interesting to note that if the logarithms of the numbers representing the several floods are used instead of the numbers themselves, the agreement with the normal law of error is closer. In other words, the variations up and down from the mean follow a geometric rather than an arithmetical ratio.

If the records of the floods of a number of streams were available for very long terms, it would be possible to find a "standard variation" and a "coefficient of variation" from the records of each stream, which would be an index of the degree of variability to be expected in its floods, and indirectly of the size of the floods to be anticipated. There is no reason to suppose that the coefficients of variation in flood flows for different streams would be the same. However, short-term data are not sufficient to determine the coefficient of variation with the requisite degree of accuracy to make this comparison; and the assumption tacitly made by Mr. Fuller, that the coefficient of variation

Mr. Hazen. of all the streams in one geographical group will be the same, may be found to be nearly in accordance with the facts. At any rate, the data now available are not sufficient to justify a further classification.

The constants found in the proposed flood-flow formula deduced for rivers in different parts of the United States throw some light on this point. If the coefficients of variation in flood flows in different parts of the country differed considerably, there would be differences in these constants. The smallness of the differences found by the author indicates a surprising degree of uniformity in flood conditions for a large part of the country, and this uniformity by districts may be taken as an indication of the probable absence of wide variations among different streams in the same district.

To attempt to secure actual coefficients from the data at hand, and to compare with one another streams having records no longer than are now available, is like attempting to find the probability of a house burning down from the records of single houses.

In the practical application of the author's formula, the value of the coefficient to be multiplied by $A^{0.8}$ to produce the average annual flood, is a matter of the first importance. In only a limited number of cases will it be possible to base such estimates on actual gaugings of the stream for which estimate is to be made. In a majority of cases, it will be necessary to depend on the records of other streams more or less similarly situated.

On Fig. 7, an outline map of the United States, the coefficients for the streams, for which Mr. Fuller presents data, have been plotted. This map serves conveniently to show what data are available at this time. It is seen that there are large parts of the United States which are not covered at all, and others which are covered most inadequately. In forming judgment as to the probable value of the coefficient to be used for other areas, it will naturally be borne in mind that the coefficient increases with the rainfall, with the elevation, especially with the steepness of the catchment area, and with the absence of natural storage conditions. With these matters in mind, it may be possible, in many cases, to form an idea as to the coefficient to be expected, sufficiently close to be useful, even from the existing limited data. With a continuation of the present gaugings by the U. S. Geological Survey and by other parties, the available data will be enormously increased in the next decade.

One of the most important matters developed by the paper is that there is no such thing as a maximum flood. There is an annual flood which must be expected every year. There is a 10-year flood which is much greater. There is a 100-year flood much greater than the 10-year flood; and, although no records are at hand to demonstrate it adequately, there is every reason to believe that there is a 1 000-

Mr. Hazen.

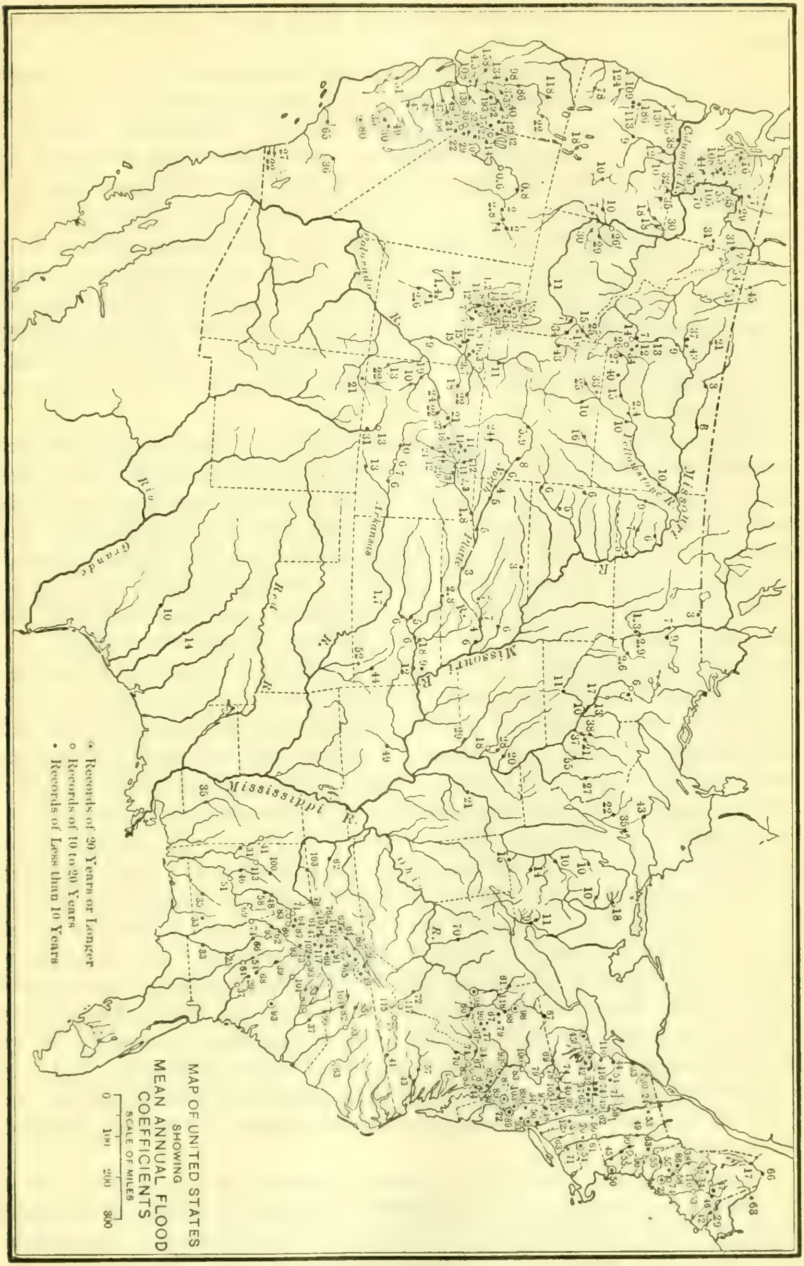


FIG. 7.

Mr. Hazen. year flood, which will prove to be very much greater than the 100-year flood.

Perhaps the best practical idea of the significance of these figures may be obtained by considering them from the standpoint of insurance; that is to say, there is one chance in ten that the 10-year flood will occur in any one year; one chance in one hundred that the 100-year flood will occur; and one chance in 1 000 that the 1 000-year flood will occur.

However great the flood which may have been experienced, it may be taken as an assured fact that it is only a question of time when a larger one will occur. In long-continued flood records, the second largest flood is found to be, on an average, about 80% of the greatest one. It follows that when the flood record of any stream is exceeded, the probabilities are that the new record will exceed the old one by 25 per cent.

The author's formula relates to the volume of flood to be expected, in cubic feet per second. Many important flood records are not available in these terms. It is known how high the water went, but it is not known with any degree of certainty how many cubic feet per second went down the stream. Gauge-height data are not applicable directly to study in connection with the author's formula, but, nevertheless, they may be used as a basis for estimating the probable height of future floods, as long as the conditions of channel remain unchanged; that is to say, as long as the conditions remain such that the same volume of discharge may be expected to produce the same or nearly the same height of water. Within this limit, as the quantity of discharge, or some function of it, follows approximately the normal law of error, and as the height of water is a function of the quantity of discharge, it follows that the height of water, or some function of it, will follow approximately the normal law of error; and, with constant channel conditions, the records of gauge heights for a term of years may be arranged in the order of magnitude and plotted, as the author has plotted his flood data, on logarithmic paper, or as the writer would prefer, on the probability paper previously described. An illustration of this method is presented in Fig. 8, which shows the gauge heights of the Ohio River at Cincinnati, arranged in this way. The results thus plotted may be used as a basis for a graphical determination of the probability of recurrence of floods of various heights, and the reasonable projection of the mean line may be taken as giving an idea of the probable frequency of floods greater than those covered by the record.

This method of analysis, of course, ceases to be applicable as soon as there are changes in the channel. A study of certain flood data indicates that the Mississippi records above Memphis, and the records of many other rivers which have not changed their channels, can be

Mr. Hazen.

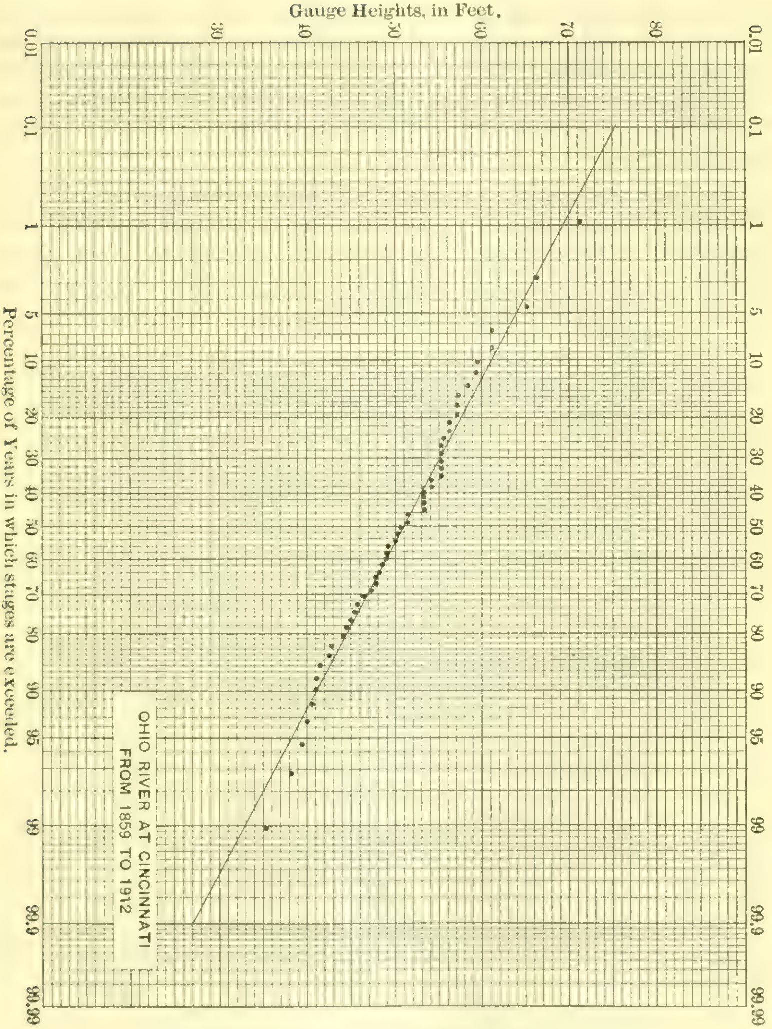
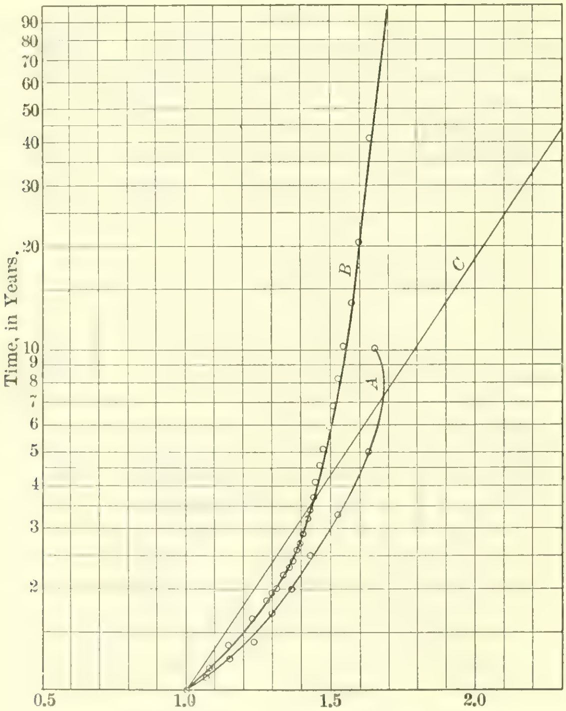


FIG. 8.

Mr. Hazen. treated in this way; and, on the other hand, the records of the Lower Mississippi, owing to changing dike and channel conditions, are not capable of such use.

The writer considers that the general method of analysis proposed by the author is of the greatest importance, and is applicable to the study of many other kinds of engineering data in which unknown elements of variation play an important part; and he believes that the use of this method in arranging and studying such data may prove of even greater significance than the important results in regard to flood flows which are presented.

Mr. Knowles. MORRIS KNOWLES, M. AM. SOC. C. E.—It is always interesting and helpful when an endeavor is made to deduce general empirical relations from a large mass of accumulated engineering data. Such attempts, however, cannot emphasize too strongly the fact that



CURVE A- FLOOD FREQUENCY FOR 10-YEAR KITTANNING RECORD
CURVE B- FLOOD FREQUENCY FOR 41-YEAR KITTANNING RECORD
CURVE C- FLOOD FREQUENCY ACCORDING TO MR. FULLER'S EQUATION.

FIG. 9.

these obtained relations hold good only for the data from which they were derived, and must not be extended to others without the greatest precaution. Unfortunately, too many of the younger engineers and recent graduates are apt to jump to the conclusion that such studies, because published by the Society, are of general application, and put them to uses for which they were never intended. The author is very careful in this respect, and refrains from making any claim as to the universal application of his equations. It would be well, however, if the opposite were more strongly emphasized, and it may not be amiss if some examples are given to illustrate divergence from the laws deduced. Mr. Knowles.

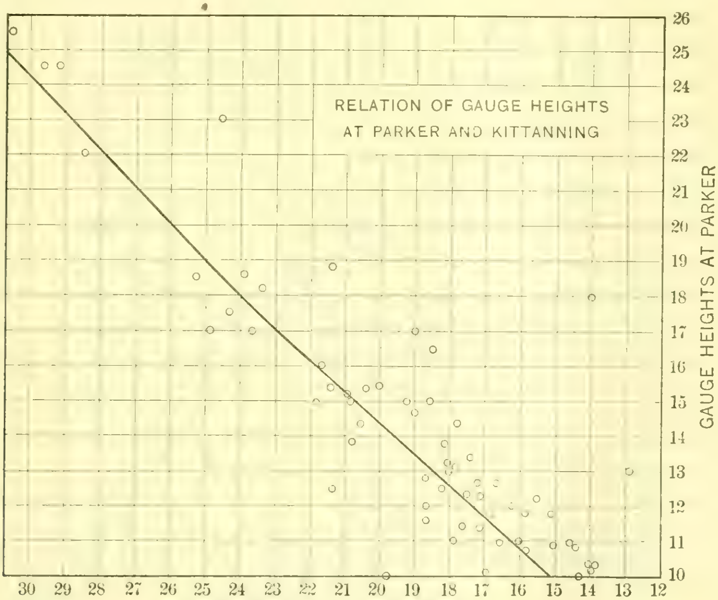


FIG. 10.

Point is given to these remarks by the fact that, at about the time this paper was published, the speaker was interested in investigating the magnitude and frequency of floods on the Allegheny River at Kittanning, Pa., and was led to check up the relation between average and maximum floods as shown by the records with that indicated by the author. The results may be of some interest.

Gaugings of the Allegheny River at Kittanning are now available for 10 years. The gauge was established by the United States Geological Survey in 1904, and remained under its jurisdiction until 1907, when it was taken over by the Water Supply Commission of Pennsylvania. The annual maximum 24-hour discharges have been de-

Mr. Knowles.

duced from the readings of this gauge, by the rating table of the Water Supply Commission, extrapolating for stages in excess of 25.0 ft.

Following the methods used by the author in compiling Table 5, the results shown in Table 32 are obtained.

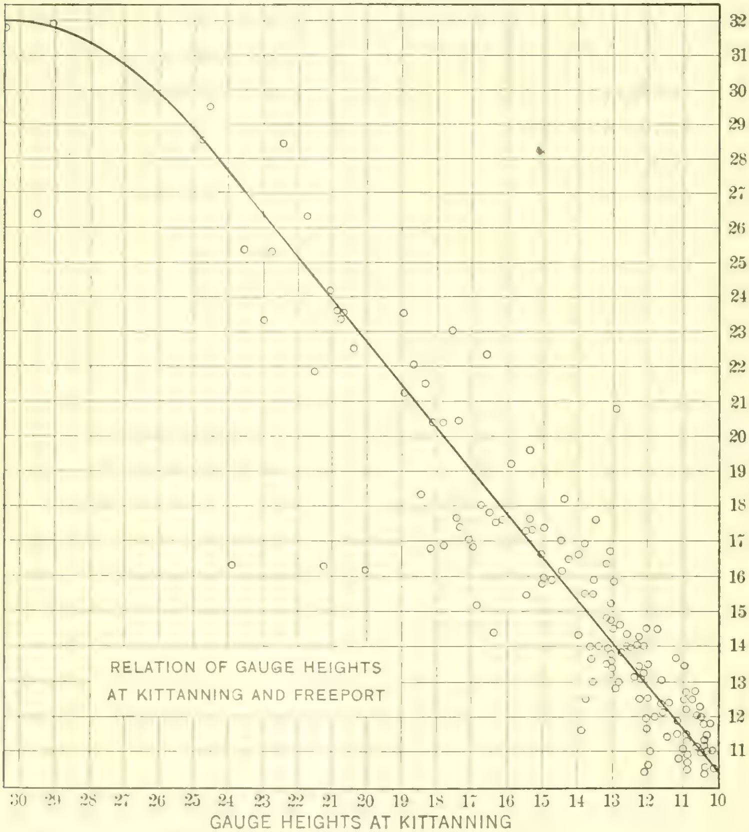


FIG. 11.

Plotting the values in Columns 7 and 8 on logarithmic paper, as was done for Curve A on Fig. 1, gives the curve, A, on Fig. 9. This is interesting in that it is not a straight line, as is the case for all the rivers for which plots were made by the author.

With the idea of studying the effect of increasing the period of observation, an attempt was made to complete the Kittanning record for a total of 41 years, by studying the relation of recorded gauge readings at Kittanning with those at Freeport and Parker. The gauge

TABLE 32.—PROBABLE AVERAGE MAXIMUM FLOOD TO BE EXPECTED IN THE ALLEGHENY RIVER AT KITTANNING. Mr. Knowles.

Average Yearly Flood = 148 200 sec-ft.

No. of flood, in order of magnitude. (1)	Year. (2)	Gauge height, in feet. (3)	Discharge, in second-feet (4)	Ratio of flood to average yearly flood. (5)	Summation of ratios. (6)	Summation of ratios divided by number of flood. (7)	Time, in years. (8)
1	1913	29.5	247 500	1.67	1.67	1.67	10
2	1905	28.2	234 200	1.58	3.25	1.63	5
3	1908	24.3	190 200	1.30	4.55	1.52	3.3
4	1912	23.0	172 000	1.16	5.71	1.43	2.5
5	1909	22.8	168 800	1.14	6.85	1.37	2.0
6	1910	20.8	139 100	0.94	7.79	1.30	1.7
7	1911	19.1	118 000	0.79	8.58	1.23	1.4
8	1907	15.9	86 500	0.59	9.17	1.15	1.25
9	1906	14.0	69 100	0.47	9.64	1.07	1.1
10	1904	12.4	56 100	0.38	10.02	1.00	1.0

at Freeport, 26 miles below Kittanning, was established in 1873, and that at Parker, 39 miles above Kittanning, in 1884. As Freeport is at the mouth of the Kiskiminetas River, one of the largest tributaries of the Allegheny, and as no important tributaries enter at Parker or between Parker and Kittanning, it was thought that a more constant relation might be expected between the gauges at Kittanning and Parker, than between those at Kittanning and Freeport.

All gauge readings of 10 ft. or more at Kittanning since 1904, therefore, were plotted, with the corresponding gauge readings at Parker and Freeport, as shown in Figs. 10 and 11. Estimated Kittanning gauge heights were taken from the Freeport curve for the period 1873-84, and from the Parker curve for 1884-1904. In plotting the Freeport-Kittanning curve, all points representing local floods in the Kiskiminetas River were given less weight.

Estimating the corresponding discharges from the same rating curve, and proceeding as before, gives the results shown in Table 33.

Plotting Columns 7 and 8 of Table 33 on logarithmic paper gives Curve *B* on Fig. 9. This, also, is not a straight line, and though its upper portion is nearly straight, the line does not pass through the point ($R = 1$, $T = 1$) as would be required by the equation:

$$R = 1 + 0.8 \log. T.$$

Curve *C*, Fig. 9, shows the author's equation, and indicates that its use would yield results too large, or on the side of safety, as compared with the computed expectancies, for all periods in excess of 5 or 6 years.

Mr. Knowles.

TABLE 33.—PROBABLE AVERAGE MAXIMUM FLOOD TO BE EXPECTED IN THE ALLEGHENY RIVER AT KITTANNING, 1873-1913, INCLUSIVE.

Average Yearly Flood = 151 300 sec-ft.

No. of flood in order of magnitude. (1)	Year. (2)	Gauge height, in feet. (3)	Discharge, in second-feet. (4)	Ratio of flood to average yearly flood. (5)	Summation of ratios. (6)	Summation of ratios divided by number of flood. (7)	Time, in years. (8)
1	1913	29.5	247 500	1.63	1.63	1.64	41.0
2	1905	28.5	234 200	1.56	3.19	1.60	20.5
3	1886	27.7	229 200	1.51	4.71	1.57	13.7
4	1883	26.8	220 000	1.45	6.16	1.54	10.2
5	1891	26.7	218 900	1.44	7.60	1.52	8.2
6	1884	26.3	214 400	1.42	9.02	1.50	6.8
7	1900	26.0	211 000	1.39	10.42	1.50	5.9
8	1881	25.7	207 500	1.37	11.79	1.47	5.1
9	1892	25.6	206 400	1.36	13.15	1.46	4.6
10	1890	25.1	200 400	1.32	14.48	1.45	4.1
11	1895	25.1	200 400	1.32	15.80	1.44	3.7
12	1904	25.0	199 150	1.31	17.12	1.43	3.4
13	1887	24.7	195 400	1.29	18.41	1.42	3.2
14	1908	24.3	190 200	1.25	19.66	1.41	2.9
15	1894	24.1	187 600	1.24	20.90	1.40	2.7
16	1902	24.1	187 600	1.24	22.14	1.39	2.6
17	1912	23.0	172 000	1.13	23.28	1.37	2.4
18	1909	22.8	168 800	1.11	24.39	1.36	2.3
19	1893	21.8	153 000	1.00	25.39	1.34	2.2
20	1910	20.8	139 100	0.92	26.31	1.32	2.0
21	1903	20.7	137 800	0.91	27.22	1.30	1.95
22	1878	20.3	132 800	0.88	28.10	1.28	1.86
23	1882	20.3	132 800	0.88	28.98	1.26	1.78
24	1879	20.0	129 200	0.85	29.83	1.25	1.71
25	1898	19.6	124 700	0.82	30.65	1.23	1.64
26	1911	19.1	118 000	0.78	31.43	1.21	1.58
27	1875	18.6	113 600	0.75	32.18	1.19	1.52
28	1885	18.4	111 500	0.74	32.92	1.18	1.47
29	1896	18.4	111 500	0.74	33.66	1.16	1.41
30	1898	18.4	111 500	0.74	34.39	1.15	1.37
31	1901	18.4	111 500	0.74	35.13	1.14	1.32
32	1897	18.2	109 400	0.72	35.85	1.12	1.28
33	1888	17.8	105 300	0.70	36.56	1.11	1.24
34	1877	17.1	98 100	0.65	37.20	1.10	1.21
35	1876	17.0	97 100	0.64	37.84	1.08	1.17
36	1874	16.7	94 100	0.62	38.46	1.07	1.14
37	1889	16.4	91 300	0.60	39.06	1.06	1.11
38	1907	15.9	86 500	0.57	39.64	1.05	1.08
39	1899	14.5	73 500	0.49	40.12	1.03	1.05
40	1906	14.0	69 100	0.46	40.58	1.01	1.02
41	1880	13.0	60 800	0.40	40.98	1.00	1.00
			6 202 850	Average = 151 300			

It may not be without interest to add that several attempts were made to obtain an equation which would fit Curves A and B, and it was found that the following checked closely for values of T greater than 2 years:

$$\text{For Curve } A,\ Q = Q\ (\text{Ave.})\ (1.7 + 0.6 \log. \log. T)$$
$$\text{For Curve } B,\ Q = Q\ (\text{Ave.})\ (1.6 + 0.6 \log. \log. T)$$

Graphs of these are shown on Fig. 12.

It should be noted in passing that the average annual flood computed by the speaker for the 10-year record at Kittanning, or for any conservative 7 years of that record, is substantially greater than that given by the author for the Allegheny River at Kittanning in Table 16. No doubt this is due to the use of a different rating curve in connection with the gaugings. Mr. Knowles.

CURVE A. $Q=Q$(AVE.) (1.7+0.6 LOG. LOG. T)10-YEAR RECORD.
CURVE B. $Q=Q$(AVE.) (1.6+0.6 LOG. LOG. T)41-YEAR RECORD.

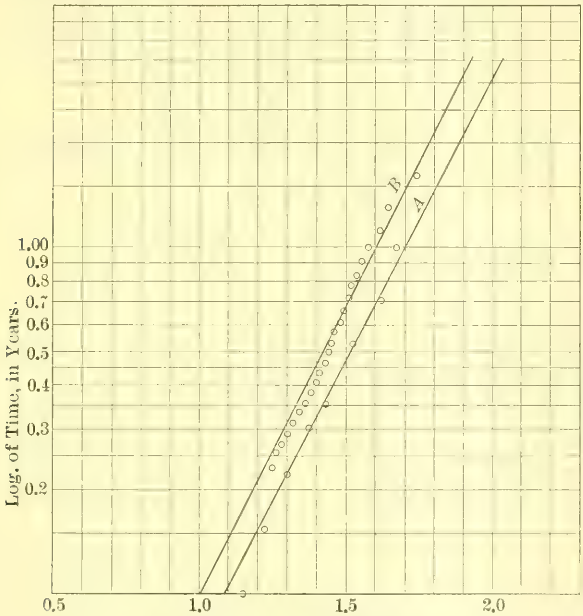


FIG. 12.

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PAPERS AND DISCUSSIONS

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CONCRETE BRIDGES: SOME IMPORTANT FEATURES IN THEIR DESIGN.

Discussion.*

By S. W. Bowen, M. Am. Soc. C. E.

S. W. Bowen, M. Am. Soc. C. E. (by letter).—The writer is much interested in this paper, especially in that portion relating to three-hinged ribbed arches. The comparisons of cost of the three-hinged and fixed types seem to indicate that the former is not such an expensive form of construction as we are sometimes led to believe. The comparison, however, is incomplete, as the cost of the rib reinforcement is not included. A fair comparison of the two types cannot be made without including this item. Mr. Bowen.

As pointed out by the authors, the three-hinged arch possesses a number of advantages over the fixed type, not the least of which is the certainty and simplicity of the calculations. One cannot carry through even the more simplified theories of fixed-arch design without being impressed by the length and complicated nature of the computations involved. These computations are based on assumptions which may not be strictly correct and may be entirely upset by a slight movement of one of the supports, to say nothing of the complications caused by temperature. In comparison with this, there is little, if any, uncertainty in the design of a three-hinged arch. The computations are simple, and the stresses in the ribs can be ascertained as accurately as the dead and live loads.

In some reinforced concrete viaducts, designed recently by the writer, cast-steel hinges having hemispherical, ball-and-socket joints

* This discussion (of the paper by Walter M. Smith, Sr., M. Am. Soc. C. E., and Walter M. Smith, Jr., Jun. Am. Soc. C. E., published in August, 1913, *Proceedings*, and presented at the meeting of November 5th, 1913), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

Mr. Bowen. were used. The price paid for these castings was 7 cents per lb. in place, which is high. Even at this price, the cost of the hinges amounted only to about $3\frac{1}{2}\%$ of the cost of the structure. This does not seem to be an extravagant price, considering the many advantages obtained. The writer believes that more can be gained by developing a cheap form of hinge than by producing new theories of fixed-arch design.

With reference to the ribbed type, as compared with the solid arch ring or barrel type, the former has one advantage over the latter which is not brought out by the authors: This is the fact that no water-proofing is required where ribbed arches are used. Water-proofing is frequently an expensive and troublesome proposition, and the type of construction that does away with it is worthy of consideration for that reason alone.

As to the I-shaped section for the ribs of long spans, it is doubtful whether this cross-section is much more economical than the rectangular section. The forms for the former will be more expensive per cubic yard of concrete than those for the latter, and the cost of placing concrete in the I-section will be greater per cubic yard than in the rectangular section. This will tend to reduce the difference in cost due to the smaller yardage of concrete in the I-section.

In conclusion, the writer wishes to state that he agrees fully with the authors as to the advantages of the three-hinged ribbed arch over other types of arch, and believes that this valuable paper will do much toward bringing this type into more general use.

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DERIVATION OF RUN-OFF FROM RAINFALL DATA.

Discussion.*

By R. B. H. Begg, Assoc. M. Am. Soc. C. E.

R. B. H. Begg, Assoc. M. Am. Soc. C. E. (by letter).—Mr. Justin's paper is an interesting addition to an important subject, but the writer would like to call attention to the danger of attempting to apply any general formula to so complicated a matter as the relation of rainfall to run-off, and, at the same time, present a hitherto unpublished run-off curve (Fig. 21), which may be of interest. This curve shows the relation of run-off to rainfall for the principal water-sheds of Kansas. The run-off figures were taken from the stream guagings of the U. S. Geological Survey, and the rainfall from the reports of the U. S. Weather Bureau. The points plotted, with very few exceptions, fell very close to the final curve. The principal point of interest in this curve is the great difference between it and the curves for the Northeastern States, which are the ones usually seen. Mr. Begg.

The conditions governing the run-off in Kansas are quite different from those in the East; of these the two most important are the slight slope of the drainage areas and the fact that the greatest rainfall occurs in summer, when vegetation is most abundant, and, consequently, evaporation from the ground is greatest. It will be noticed that, for a rainfall of 40 in. on the water-sheds mentioned by Mr. Justin, the run-off is about 18 in., and the curve for Kansas gives only 6.1 in.

Mr. Justin gives the general formula, $C = 0.934\, S^{0.155} \dfrac{R^2}{T}$, for the run-off. The curve plotted by this formula for the Republican River, one of the principal streams used in the diagram, Fig. 21, is on the same scale. It will be noted that this formula gives results about 40% greater than those obtained from the curve plotted from actual measurements for rainfalls of 30 in. or more, and for smaller rainfalls it gives even greater discrepancies. The writer attempted unsuccessfully to derive a formula that would fit this curve, and came

* Continued from October, 1913, *Proceedings*.

Mr. Begg.

to the conclusion that no formula would fit Kansas conditions, the principal difficulty being that the variation in rainfall from year to year is much greater than in the East, the driest year being about 50% of the average instead of 70%, and no formula could be found to fit a long enough portion of the curve to cover the ordinary variations.

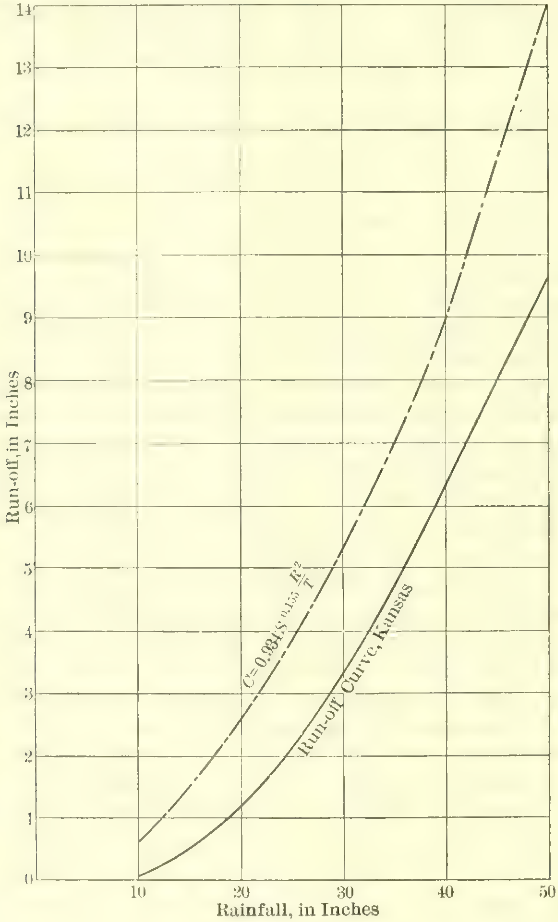

FIG. 21.

Much trouble has been caused in various parts of the country by calculating water supplies from data and formulas compiled for use in places where the conditions are entirely different, and it would be of great service to water-works engineers if reliable data were available for all localities, and attempts to derive formulas for general application were abandoned.

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THE EFFECT OF SATURATION ON THE STRENGTH OF CONCRETE.

Discussion.*

By Messrs. E. A. Moritz, J. R. Worcester, Walter S. Wheeler, and Clifford Richardson.

E. A. Moritz, Assoc. M. Am. Soc. C. E. (by letter).—This paper recalls some experiments conducted by the writer in 1904 and 1905 at the University of Wisconsin and published in 1906.† It was believed by the writer at that time that concrete stored in water before testing is much stronger than when stored in air for the same period of time, and he was much surprised then, and has been more surprised since, that this point has not been generally recognized in specifications for test pieces. Mr. Moritz.

The writer's experiments were very limited, and were only incidental to some tests of large beams, but the results show up so forcibly the difference in strength of concrete specimens stored in water and those stored in air that it is thought worth while to publish them again in connection with Mr. Van Ornum's paper. The figures in Table 1 are taken from page 364 of the *Bulletin* mentioned. The figures in the last column are the reciprocals of those in the *Bulletin*, and are given in order to make them directly comparable with Mr. Van Ornum's figures.

All compression tests were made with 4-in. cubes, and at the age of 30 days. The cubes were taken from the moulds at the age of 48 hours, after which one from each batch was stored in air at a

*This discussion (of the paper by J. L. Van Ornum, M. Am. Soc. C. E., published in August, 1913, *Proceedings*, and presented at the meeting of November 5th, 1913), is printed in *Proceedings*, in order that the views expressed may be brought before all members for further discussion.

† *Bulletin No. 148*, Univ. of Wisconsin.

Mr. Moritz. temperature of about 65°, and the other stored in water until tested. The concrete was mixed moderately wet—not sloppy. All materials were proportioned by weight and mixed by hand. Natural pit sand and crushed limestone formed the aggregate.

TABLE 1.

Proportions of concrete.	Unit Stress on Cube: In water, S_1.	Unit Stress on Cube: In air, S_2.	Ratio, $\frac{S_1}{S_2}$
1 : 2 : 5	1 450	1 170	1.23
"	2 720	1 420	1.92
"	2 060	1 600	1.28
"	2 560	1 310	1.96
"	2 560	1 290	2.00
"	2 850	1 620	1.75
"	2 620	1 560	1.70
1 : 3 : 6.5	1 950	990	1.96
"	1 620	950	1.70
"	1 180	780	1.51
"	1 520	1 020	1.49
"	1 610	1 050	1.54

Mr. Worcester. J. R. Worcester, M. Am. Soc. C. E. (by letter).—The author has brought out in a forceful manner the possible loss of strength in concrete by saturation after premature drying, and, at the same time, the possible gain in strength by continuous saturation up to an age of 6 weeks. This series of tests furnishes ample evidence of the necessity of standardizing the method of curing specimens for compression tests in the laboratory, and may account for an appreciable part of the discrepancies often noticed between the results of experiments made in different laboratories. It also shows that by yielding to the temptation to allow concrete in actual construction to dry out as rapidly as possible, one runs the risk of permanently losing a very material proportion of the strength which might be attained, even though, by its location within a building, there is no danger of the loss of strength through subsequent saturation. Builders are very apt to strip forms from vertical surfaces as quickly as possible, to hasten this drying out, and engineers are likely to overlook the ill effect of this practice.

It seems evident that the treatment to which the test specimens were subjected was calculated to produce unusually rapid drying out, and that the strength of those tested without subsequent immersion, taken as 100 on the scale of relative strengths, must have been rather lower than would naturally be expected of this quality of concrete. If so, the later gain in strength after continuous saturation is easily explained. The author, perhaps, will give us additional light on this point.

The temporary loss of strength on immersion appears to the writer to be analogous to the loss in strength of dried clay when water-soaked. It seems as if some of the cement was dried out so rapidly that it acquired a strength from drying and not from chemical crystallization. The formation of a hardened, light colored skin on the outside of a wall while the interior is still dark, moist, and soft, is a common phenomenon. If this is not the true explanation, the writer hopes that the discussion will bring out a better one. Mr. Worcester.

Although the report of the Special Committee on Concrete and Reinforced Concrete does not elaborate the dangers of too rapid drying, as it might have done to advantage, it does include one recommendation, apparently overlooked by the author, that "The faces of concrete exposed to premature drying should be kept wet for a period of at least 7 days." It would be interesting to know what would have been the effect on the author's experiments of this initial treatment.

In actual construction it seems probable that generally a better chance for hydration exists than was given to these specimens. A cylinder, 8 in. in diameter and 16 in. high, removed from the mould in 2 days and exposed to air of ordinary humidity, would present a large surface to the effect of evaporation, and would dry out very rapidly. The exposed surface, assuming the cylinders to have stood on end, would have amounted to about 6.75 sq. ft. for each cubic foot of volume. In practice, prior to the removal of the forms, a floor slab would offer the largest exposed surface per unit of volume of any ordinary construction. In this case, with a thickness of 6 in., the exposed area would only be 2 sq. ft. for every cubic foot of volume, and, if the surface were kept wet for 7 days, as it should be, the chance for drying out would be much less than in the test cylinders. It appears, therefore, that though the danger of a decrease in strength from saturation is unlikely to prove serious in practice, it cannot justifiably be ignored.

Walter S. Wheeler, M. Am. Soc. C. E. (by letter).—The writer has often noticed that in finished structures new concrete appears to lose part of its strength when first submerged in water. For example, he has just completed some construction in which the proportion was 1 part cement to 3 parts sand, by volume. When 2 or 3 days old, the top of this structure was submerged to a depth of about 1 ft. Before submersion, it was noted that, by pressing with the thumb on the corners and edges of the structure, the concrete could be broken quite easily, and that for several days after submersion it could be broken more easily; in fact, for a few days, it seemed that the structure had only about enough strength to hold together. Mr. Wheeler.

After a submersion of 2 months, the structure was as firm as could be expected, and nothing but a charge of dynamite could mar it. The

Mr. Wheeler. materials used were standard, and the placing was done according to standard practice.

Mr. Richardson. CLIFFORD RICHARDSON, M. AM. SOC. C. E. (by letter).—The conclusions arrived at by Mr. Van Ornum can be confirmed by the experience of the writer, who, however, would go farther and state that a reversal of the conditions with which he has experimented would result in the diminution of the strength of the concrete; that is to say, that a concrete which has been immersed in water for some time loses strength on being dried out. It is to be hoped that Mr. Van Ornum, through some of his students, will conduct some experiments in this as well as in other directions where modification of the environment of concrete may take place. Mr. Van Ornum's paper is valuable, as it brings to the attention of users of concrete a situation which has not been sufficiently appreciated in the past, although it has been known, in a general way, to most engineers.

MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

FREDERIC DANFORTH, M. Am. Soc. C. E.*

DIED JUNE 6TH, 1913.

Frederic Danforth, the son of Judge Charles and Julia S. (Dinsmore) Danforth, was born at Gardiner, Me., on February 8th, 1848. He was graduated from Dartmouth College (Thayer College of Civil Engineering) in 1870, and began work as Rodman on the construction of the European and North American Railroad, in August, 1870.

From that time until his death, he was almost constantly connected with railway work in various capacities, being employed as follows: by the Augusta and Wiscassett Railroad, from October, 1871, to May, 1872; Bartlett Division of the Portland and Ogdensburg Railroad (now the Mountain Division of the Maine Central Railroad), from August, 1872, to October, 1873; Boston and Northwestern Railroad in 1874; West Waterville and Augusta Railroad and the Augusta and Lewiston Railroad in 1875; the European and North American Railroad and the Penobscot River Railroad, from 1876 to 1881; the Gardiner and Farmington Railroad and the Aroostook Central Railroad in 1881; the Skowhegan and Athens Railroad in 1882; the Maine Shore Line Railroad and the Mt. Desert Railway in 1883; the Franklin and Megantic Railway in 1884; the Northern Maine Railroad, as Chief Engineer, in 1888 and 1889; the Kennebec Central Railroad, as Chief Engineer, from 1888 to 1890; the Portland and Rumford Falls Railroad, as Chief Engineer, from 1891 to 1894; the Maine Central Railroad in 1901; the Debec Junction Railroad in 1905; the Eastern Maine Railroad, as Chief Engineer, in 1911 and 1912.

Contemporaneously with this work, Mr. Danforth was engaged in land and city surveys in Gardiner, Me., and in surveys of townships in the State. In 1882, he designed the dam for the Augusta Water Company. He also served as City Engineer of Gardiner for a long period.

In November, 1894, he was appointed Engineer Member of the Board of Railroad Commissioners of Maine, and was re-appointed in November, 1897. He was elected Mayor of Gardiner in March, 1901, and re-elected in 1902; he also served as a member of the Board of Trustees of the Gardiner Water District in 1904. Mr. Danforth was frequently employed as Supreme Court Referee in the adjustment of disputed township boundaries and other engineering questions. On

* Memoir prepared by W. W. Crosby, M. Am. Soc. C. E.

his appointment as member of the Board of Railroad Commissioners, he resigned his official connection with several railroads in Maine, and thereafter practiced extensively as Consulting Engineer, especially for railroads and bridges. At the time of his death, he was a Director of the Gardiner National Bank.

In 1880 Mr. Danforth was married to Miss Caroline Stevens, of Randolph, Me., who, with four children, survives him.

Mr. Danforth was a man with great practical, as well as theoretical, knowledge, and of rare common sense. He was a careful, accurate, and hard worker, and, in railroad location, had few, if any, equals, his methods for such work embodying the highest kind of science. He had strong domestic tastes, and was kindly and considerate in the extreme, though of a retiring disposition. He inspired the sincere affection and regard of his subordinates and of all who knew him, and his judgment and advice were frequently sought and always generously given. He was highly respected everywhere for his character and ability. He was devoted to his profession and inspired that devotion in the other members of it with whom he came in contact. Truth and honesty stood above all to him, and in all his life he unswervingly insisted that every action or decision should be based on them. The Profession, as well as his own immediate circle, suffers an immeasurable loss in his death.

Mr. Danforth was a Member of the Thayer Society of Civil Engineers and the Maine Society of Civil Engineers. He was elected a Member of the American Society of Civil Engineers on September 2d, 1891.

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"**STORAGE TO BE PROVIDED IN IMPOUNDING RESERVOIRS FOR MUNICIPAL WATER SUPPLY.**" ALLEN HAZEN. (To be presented Dec. 17th, 1913.)

"**THE DEPRECIATION OF PUBLIC UTILITY PROPERTIES AS AFFECTING THEIR VALUATION AND FAIR RETURN.**" JOHN W. ALVORD. (To be presented Dec. 17th, 1913.)

"**PAINTING STRUCTURAL STEEL: THE PRESENT SITUATION.**" A. H. SABIN. (To be presented Jan. 7th, 1914.)

"**STRESSES IN WEDGE-SHAPED REINFORCED CONCRETE BEAMS.**" WILLIAM CAIN.

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SOCIETY AFFAIRS

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MINUTES OF MEETINGS

OF THE SOCIETY

November 19th, 1913.—The meeting was called to order at 8.30 P. M.; Director Robert Ridgway in the chair; Chas. Warren Hunt, Secretary; and present, also, 130 members and 20 guests.

A paper by Richard R. Lyman, Assoc. M. Am. Soc. C. E., entitled "Measurement of the Flow of Streams by Approved Forms of Weirs, with New Formulas and Diagrams," was presented by Weston E. Fuller, M. Am. Soc. C. E., and communications on the subject from Messrs. E. A. Moritz, Allen Hazen, and Clarence T. Johnston, were read by the Secretary.

The Secretary announced that the following members of the Society had been appointed by the Board of Direction as a Special Committee to Study the Question of Floods, Flood Prevention, and other allied subjects: Frank M. Kerr, John A. Bensel, T. G. Dabney, C. E. Grunsky, Morris Knowles, J. B. Lippincott, Daniel W. Mead, John A. Ockerson, Arthur T. Safford, Charles Saville, F. L. Sellew, and C. McD. Townsend.

The Secretary announced the election of the following candidates on November 12th, 1913:

As Members

William Bement Claflin, West Redding, Conn.
Ruel Keith Compton, Baltimore, Md.
George Henry Davis, New Orleans, La.
James Addison Guttridge, Brown Station, N. Y.
Paul Mayer LaBach, Chicago, Ill.
John William Link, Chicago, Ill.
Daniel Howard Martin, Brookville, Pa.
Harry Edgar Trout, Sault Ste. Marie, Mich.

As Associate Members

Thomas John Allan, Oakland, Cal.
George Edward Bell, Winnipeg, Man., Canada
Harry Walton Bell, Laurel, Miss.
Guy Borden, Beristain, Puebla, Mexico
Ealy Grannis Briggs, Seney, Mich.
Owen Long Burdett, Buffalo, N. Y.
Eugene Olaf Christiansen, Hilo, Hawaii
Rapier Redmond Coghlan, Elephant Butte, N. Mex.
Charles Judson Colgan, Olympia, Wash.
Harold Conkling, Boise, Idaho
Chester Cooke, Kansas City, Mo.
Ralph Emerson Dodge, Sacramento, Cal.
Rollo Guy England, Jackson, Mich.
Albert Givan, Sacramento, Cal.
Leo Adolph Hoynck, Houston, Tex.
Ellis Hudman, Rock Springs, Wyo.
Charles Clayton Huff, Los Angeles, Cal.
Louis De Cou Kelsey, Aberdeen, Wash.
George Dallis Dixon Kirkpatrick, Salt Lake City, Utah
Otto Lemberger, New York City
Edward Manhard, Rock Island, Ill.
Frank Milton Masters, New York City
Wayne Dickson Maxwell, Sac City, Iowa
Carroll Moses, New Orleans, La.
John Aloysius O'Donnell, Albany, N. Y.
Robert Franklin Olds, Fort Mills, Philippine Islands
Guy Pinner, New York City
Richard Sachse, Berkeley, Cal.
Benjamin Baker Skinner, New York City
Herbert Yates Smith, Atlantic City, N. J.
Edward Sattley Stafford, Florence, Ariz.
Russell Howard Stalnaker, Redding, Cal.

As Juniors

Charles Nicholas Bley, Berkeley, Cal.
Edward Withers Bowen, Charlotte, N. C.
Horace Morton Bringhurst, Seattle, Wash.
Walter Foster Britton, Trenton, N. J.
George Franklin Brown, Kansas City, Mo.
Asa B Chapman, Seattle, Wash.
Herbert Greiss Croll, Toronto, Ont., Canada
Joseph Jay Durfee, Brooklyn, N. Y.
Henry William English, Manning, Iowa
Charles Hinde, Vancouver, B. C., Canada
Arthur Klock Hinds, Cap Sante, Que., Canada
William Guirey Huxtable, Ebony, Ark.
Robert Lane James, Washington, D. C.
Frederick Thurlough Morse, Tropico, Cal.
John Nathanael Olson, Denison, Tex.
Jesse Hope Peek, Philadelphia, Pa.
Harry Paul Piper, Jr., Morristown, N. J.
Henry Malcolm Priest, Littleton, Mass.
John Robert Stallings, Little Rock, Ark.
Mau Sun, New York City

The Secretary announced the transfer of the following candidates on November 12th, 1913:

From Associate Member to Member

Arthur Burling Foote, Grass Valley, Cal.
Alfred Cookman Gregory, Trenton, N. J.
Adolph Frederick Meyer, St. Paul, Minn.
Henry Preston Rust, New York City
Walter Bowen Saunders, Anoka, Minn.
Garfield Stubblefield, Portland, Ore.
John Taylor, Hamilton, Ont., Canada
John Edgar Van Liew, Des Moines, Iowa

From Junior to Associate Member

Ralph Robert Benedict, Kansas City, Mo.
Frank Gary Eason, Charleston, S. C.
Clesson Herbert Field, Buffalo, N. Y.
Harry Carter Gardner, Pottstown, Pa.
Leroy Race Hinman, Denver, Colo.
Reginald Truman Hurdle, Glendive, Mont.
James Vernon Phillips, Baxley, Ga.
Gilbert Small, Boston, Mass.
Edward Charles Stocker, Shanghai, China
Roger Wolcott Toll, Denver, Colo.
Thomas Harrison Winchester, Columbus, Ga.

The Secretary announced the following deaths:

David Ernest Melliss, of Mill Valley, Cal., elected Member, October 2d, 1895; died March, 1913.

Emanuel Alois Ziffer, of Vienna, Austria, elected Member, June 7th, 1893; died October 27th, 1913.

James Marcus Bandy, of Greensboro, N. C., elected Associate Member, February 4th, 1903; date of death unknown.

Adjourned.

December 3d, 1913.—The meeting was called to order at 8.30 P. M.; A. DeW. Foote, M. Am. Soc. C. E., in the chair; Charles Warren Hunt, Secretary; and present, also, 115 members and 14 guests.

The minutes of the meetings of October 15th and November 5th, 1913, were approved as printed in *Proceedings* for November, 1913.

A paper entitled "Topographical Surveys Made by the American Section of the International Boundary Commission, United States and Mexico," by W. W. Follett, M. Am. Soc. C. E., was presented by the Secretary, and the subject was discussed by R. W. Burrowes, Jun. Am. Soc. C. E. The Secretary read communications on the subject from Messrs. William B. Landreth and W. N. Brown.

A paper by J. E. Greiner, M. Am. Soc. C. E., entitled "Coal Piers on the Atlantic Seaboard," was presented by title only.

The Secretary presented an invitation, from the Directors of the American Museum of Safety, to the members of the Society to attend and take part in the International Conference of Safety and Sanitation to be held at Rumford Hall, Chemists' Building, 50 East 41st Street, New York City, December 10th, 11th, and 12th, 1913.

The Secretary announced the election of the following candidates on December 3d, 1913:

As Members

Henry Phillips Beck, Richmond, Va.
Alvin Bugbee, Trenton, N. J.
Emmett Filmore Collins, St. Louis, Mo.
Edgar Augustus James, Toronto, Ont., Canada
Alfredo Carlo Janni, St. Louis, Mo.
David Andrew Keefe, Athens, Pa.
Sverre Lund, Worcester, Mass.
Charles Dewey Martin, Merced, Cal.
Seitaro Mukasa, Tokyo, Japan
Alexander King Robertson, Vancouver, B. C., Canada
William Von Phul, New Orleans, La.

As Associate Members

Porter Hugh Albright, Los Angeles, Cal.
Charles Everett Bee, Taber, Alberta, Canada

Gilbert Kenyon Cooper, Limon, Costa Rica
Henry Philkins Drake, Pittsburgh, Pa.
Ward Hall, Irma, Cal.
Richard Ambrose Hart, Salt Lake City, Utah
William Frederick Jenrick, New York City
Joseph Arthur Kitts, Gatun, Canal Zone, Panama
Robert Douglas McLeish, Kimberly, South Africa
Willard Preston Miller, Hondagua, Philippine Islands
Erwin John Miner, Cincinnati, Ohio
Harold Marston Morse, Cleveland, Ohio
Ralph St. Lawrence Peverley, San Juan, Porto Rico
Robert Joseph Potts, College Station, Tex.
Richard Willis Rea, Ellensburg, Wash.
Joseph Eugene Root, Cincinnati, Ohio
Chester Kitch Smith, Portland, Ore.
William Hubert Vincent, New Orleans, La.

As Associate

Hugh Monroe Wilson, New York City

As Juniors

Franklin Rea Allen, Pine Bluff, Ark.
Robert Moore Angas, Hobe Sound, Fla.
Donald McCord Baker, Albuquerque, N. Mex.
Norman Nathaniel Barber, Ottumwa, Iowa
Ralph Ernest Beck, Newark, N. J.
José Manuel Cadenas, Havana, Cuba
Jacob Leslie Crane, Jr., Ann Arbor, Mich.
Mark Antony Feiner, New York City
Lyman Russell Flook, Ann Arbor, Mich.
Leslie Carl Frank, Baltimore, Md.
Edward Louis Haberle, Minneapolis, Minn.
Joseph Samuel Harris, New York City
Thomas Victor Hatcher, Fort Shaw, Mont.
Charles Sumner Henning, Jr., Vale, Ore.
Hamlin Earle Kirchgraber, New York City
Harold Gilbert McGee, Columbus, Ohio
Oscar William Melin, Waukesha, Wis.
Louis Watters Payne, Corozal, Canal Zone, Panama
Charles Millichamp Romanowitz, Alameda, Cal.
Norman Kirkwood Sheppard, Saginaw, Mich.
Gilbert Cobb Staehle, Omaha, Nebr.
Guy Burt Walker, Wilkes-Barre, Pa.
Lee Wendelboe, St. Ignatius, Mont.
Glenn Barton Woodruff, South Bethlehem, Pa.

The Secretary announced the transfer of the following candidates on December 3d, 1913:

From Associate Member to Member

Ray Howard Corey, Marshfield, Ore.
William Albert Edward Doying, Washington, D. C.
Paul Hansen, Urbana, Ill.
Harold Wellington Horne, Farmington, Conn.
John Edward Jennings, Brooklyn, N. Y.
Charles Andrew Randorf, Hamburg, N. Y.
George Edson Philip Smith, Tucson, Ariz.
Alexander Thomson, Jr., Walden, N. Y.
John Hough Wickersham, Lancaster, Pa.

From Associate to Associate Member

Edward Coe Dilworth, Pittsburgh, Pa.

From Junior to Associate Member

Louis Evans Ayres, Ann Arbor, Mich.
William Walter Bigelow, Springfield, Mass.
Josiah Richardson Brooks, Long Key, Fla.
Walter Louis DuMoulin, Morenci, Ariz.
Myron Kendall Jordan, Kansas City, Kans.
Harry Pike Letton, Washington, D. C.
Harry Gordon Payrow, Lynn, Mass.
Rowland Grenville Rice, Birmingham, Ala.
James Gordon Steese, West Point, N. Y.
Edward George Walker, Hull, England
James Madison Warner, Syracuse, N. Y.

The Secretary announced the following deaths:

George Browne Post, of New York City, elected Member, September 2d, 1896; died November 28th, 1913.

Baird Snyder, Jr., of Pottsville, Pa., elected Member, March 2d, 1904; died July 9th, 1913.

Orloff Lake, of Corey, Ala., elected Junior, December 1st, 1908; died October 21st, 1913.

Adjourned.

December 17th, 1913.—Because of the necessity of going to press with this number of *Proceedings* in advance of this meeting, the publication of its minutes must be deferred until January, 1914. Two papers have been set down for discussion: "Storage to be Provided in Impounding Reservoirs for Municipal Water Supply", by Allen Hazen, M. Am. Soc. C. E.; and "The Depreciation of Public Utility Properties as Affecting Their Valuation and Fair Return", by John W. Alvord, M. Am. Soc. C. E.

OF THE BOARD OF DIRECTION

(Abstract)

November 12th, 1913.—President Swain in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Bush, Edwards, Endicott, Hodge, Ridgway, and Snow.

Messrs. Ridgway, Hodge, and Hunt, were appointed as a Committee to take charge of the arrangements for the Annual Meeting.

The resignation of one Associate Member was accepted.

Ballots for membership were canvassed, resulting in the election of 8 Members, 32 Associate Members, 20 Juniors, and the transfer of 11 Juniors to the grade of Associate Member.

Eight Associate Members were transferred to the grade of Member.

Applications were considered and other routine business transacted.

Adjourned.

December 3d, 1913.—The Board met at 3.05 P. M.; President Swain in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Bush, Churchill, Clarke, Edwards, Endicott, Gerber, Leonard, and Ridgway.

Baltimore, Md., was chosen as the place for holding the Annual Convention in 1914, the time to be decided later.

C. E. Grunsky, M. Am. Soc. C. E., was appointed as one of the Representatives of this Society on the General Committee of Management of the International Engineering Congress, 1915, to fill the vacancy caused by the death of the late Arthur L. Adams, M. Am. Soc. C. E.

The Constitution of "The Southern California Association of Members of the American Society of Civil Engineers", which is to consist of members of the Society resident in or near Los Angeles, Cal., was approved.

George F. Swain, President, Am. Soc. C. E., was appointed a member of the John Fritz Medal Board of Award to fill the vacancy on January 16th next, which will be caused by the retirement from that Board of Onward Bates, Past-President, Am. Soc. C. E.

The resignations of two Members, and one Associate Member were accepted.

Ballots for membership were canvassed, resulting in the election of 11 Members, 18 Associate Members, 1 Associate, and 24 Juniors, and the transfer of 11 Juniors to the grade of Associate Member.

Nine Associate Members were transferred to the grade of Member, and one Associate was transferred to the grade of Associate Member.

Applications were considered, and other routine business transacted.

Adjourned.

ANNOUNCEMENTS

The House of the Society is open from 9 A. M. to 10 P. M., every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

FUTURE MEETINGS

January 7th, 1914.—8.30 P. M.—This will be a regular business meeting. A paper by A. H. Sabin, Assoc. M. Am. Soc. C. E., entitled "Painting Structural Steel: The Present Situation," will be presented for discussion.

This paper was printed in *Proceedings* for November, 1913.

Wednesday and Thursday, January 21st and 22d, 1914.—The Sixty-first Annual Meeting will be held. The Business Meeting will be called to order at 10 o'clock on Wednesday morning at the Society House. The Annual Reports will be presented, officers for the ensuing year elected, members of the Nominating Committee appointed. Reports of Special Committees presented for discussion, and other business transacted.

Arrangements for the Annual Meeting have been placed in the hands of the following committee: Messrs. Robert Ridgway, Henry W. Hodge, and Charles Warren Hunt.

February 4th, 1914.—8.30 P. M.—A regular business meeting will be held, and a paper by Edward Flad, M. Am. Soc. C. E., entitled "Reinforced Concrete Reservoir and Coagulation Plant at St. Louis, Mo.", will be presented for discussion.

This paper is printed in this number of *Proceedings.*

SPECIAL MEETINGS FOR TOPICAL DISCUSSION

On the two days immediately following the Annual Meeting, three meetings of the Society will be held, at which the subject for discussion will be "Road Construction and Maintenance."

The meetings will be held as follows:

First Meeting, Friday, January 23d, 1914.—10 A. M.—The following sub-division of the subject will be discussed:

(1) "Engineering Organizations for Highway Work."

The opening discussions on this subject will be by Samuel D. Foster, Assoc. M. Am. Soc. C. E., and William H. Connell, Assoc. M. Am. Soc. C. E.

Second Meeting, Friday, January 23d, 1914.—2 P. M.—The following sub-division of the subject will be discussed:

(2) "Factors Limiting the Selection of Materials and of Methods in Highway Construction."

The discussion on this subject will be introduced by Paul E. Green, M. Am. Soc. C. E.

Third Meeting, Saturday, January 24th, 1914.—10 A. M.—The following sub-division of the subject will be discussed:

(3) "Equipment and Methods for Maintaining Bituminous Surfaces and Bituminous Pavements."

This topic will be introduced by W. R. Farrington, M. Am. Soc. C. E.

SPECIAL COMMITTEE ON FLOODS AND FLOOD PREVENTION

At the Society meeting of May 7th, 1913, the following Resolution was presented:

"*Moved:* That the Board of Direction consider the matter of the appointment of a Special Committee to study the question of Floods, Flood Prevention, and other allied subjects."

This Resolution was referred to the Board of Direction.

The Board has appointed the following committee:

Frank M. Kerr, *Chairman,*

John A. Bensel,	Daniel W. Mead,
T. G. Dabney,	John A. Ockerson,
C. E. Grunsky,	Arthur T. Safford,
Morris Knowles,	Charles Saville,
J. B. Lippincott,	F. L. Sellew,

C. McD. Townsend.

SEARCHES IN THE LIBRARY

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

In reference to this work, the Appendices* to the Annual Reports of the Board of Direction for the years ending December 31st, 1906, and December 31st, 1910, contain summaries of all searches made to date.

PAPERS AND DISCUSSIONS

Members and others who take part in the oral discussions of the papers presented are urged to revise their remarks promptly. Written communications from those who cannot attend the meetings should be sent in at the earliest possible date after the issue of a paper in *Proceedings.*

All papers accepted by the Publication Committee are classified by the Committee with respect to their availability for discussion at meetings.

Papers which, from their general nature, appear to be of a character suitable for oral discussion, will be published as heretofore in *Proceedings*, and set down for presentation to a future meeting of the Society, and on these, oral discussions, as well as written communications, will be solicited.

All papers which do not come under this heading, that is to say, those which from their mathematical or technical nature, in the opinion of the Committee are not adapted to oral discussion, will not be scheduled for presentation to any meeting. Such papers will be published in *Proceedings* in the same manner as those which are to be presented at meetings, but written discussions, only, will be requested for subsequent publication in *Proceedings* and with the paper in the volumes of *Transactions.*

The Board of Direction has adopted rules for the preparation and presentation of papers, which will be found on page 429 of the August, 1913, *Proceedings.*

LOCAL ASSOCIATIONS OF MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

San Francisco Association

The San Francisco Association of Members of the American Society of Civil Engineers holds regular bi-monthly meetings, with banquet, and weekly informal luncheons. The former are held at 6 P. M., at the Palace Hotel, on the third Friday of February, April, June, August, October and December, the last being the Annual Meeting of the Association.

Informal luncheons are held at 12.15 P. M. every Wednesday, and the place of meeting may be ascertained by communicating with the Secretary of the Association, E. T. Thurston, Jr., M. Am. Soc. C. E., 713 Mechanics' Institute, 57 Post Street.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in San Francisco, and any such member will be gladly welcomed as a guest.

**Proceedings*, Vol. XXXIII, p. 20 (January, 1907); Vol. XXXVII, p. 28 (January, 1911).

Colorado Association

The meetings of the Colorado Association of Members of the American Society of Civil Engineers are held on the second Saturday of each month, except July and August. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary, Roger W. Toll, Assoc. M. Am. Soc. C. E., 700 Tramway Building, Denver, Colo. The meetings are usually preceded by an informal dinner. Members of the American Society of Civil Engineers will be welcomed at these meetings.

Weekly luncheons are held on Wednesdays, and, until further notice, will take place at the Colorado Traffic Club.

Visiting members are urged to attend the meetings and luncheons.

(Abstract of Minutes of Meeting)

November 14th, 1913.—The meeting was called to order; President Ridgway in the chair; Roger W. Toll, Secretary; and present, also, 22 members and 31 guests.

The minutes of the meeting of October 11th, and of the Special Meeting of November 5th, 1913, were read and approved.

The Report of the Committee appointed to determine on the best method for the Association to support the International Engineering Congress, was read and adopted, and the Committee was discharged. The Treasurer was instructed to return the contributions which had been received for a Special Fund, and the Committee urged all members of the Association to take out membership in the Congress.

A. L. Fellows, M. Am. Soc. C. E., announced that the Report of the Cherry Creek Flood Commission had been published and that copies of the same were available.

A paper by Leonard Metcalf, M. Am. Soc. C. E., on "The Valuation of Public Utilities," was presented by the author, and a vote of thanks was tendered to Mr. Metcalf for his interesting paper.

Adjourned.

Atlanta Association

On March 14th, 1912, the Atlanta Association of Members of the American Society of Civil Engineers was organized, with the following officers: Arthur Pew, President; William A. Hansell, Jr., Secretary; and Messrs. James N. Hazlehurst and B. M. Hall, Members of the Executive Committee. The Association will hold its meetings in the house of the University Club.

Philadelphia Association

At its meeting of June 4th, 1913, the Board of Direction of the Society considered and approved the proposed Constitution of the Philadelphia Association of Members of the American Society of Civil Engineers.

Portland, Ore., Association

On June 18th, 1913, the Portland, Ore., Association of Members of the American Society of Civil Engineers was organized with the following officers: E. G. Hopson, President; W. S. Turner, First Vice-President; D. D. Clarke, Second Vice-President; G. B. Hegardt, Treasurer; and Charles J. McGonigle, Secretary.

(Abstract of Minutes of Meetings)

October 27th, 1913.—At this meeting, R. G. Dieck, M. Am. Soc. C. E., Commissioner of Public Works, addressed the members on Engineering Subjects in connection with the City of Portland.

Adjourned.

November 24th, 1913.—The subject for discussion at this meeting was "Quantity Surveys". The subject was introduced by George P. Mason, M. Am. Soc. C. E., and was generally discussed by other members present.

Adjourned.

Seattle Association

On June 30th, 1913, the Seattle Association of Members of the American Society of Civil Engineers was organized with the following officers: Samuel H. Hedges, President; Ernest B. Hussey, Vice-President; and Joseph Jacobs, Secretary-Treasurer.

Southern California Association

At its meeting of December 3d, 1913, the Board of Direction considered and approved the proposed Constitution of the Southern California Association of Members of the American Society of Civil Engineers.

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms, and at all meetings:

American Institute of Mining Engineers, 29 West Thirty-ninth Street, New York City.

American Society of Mechanical Engineers, 29 West Thirty-ninth Street, New York City.

Architekten-Verein zu Berlin, Wilhelmstrasse 92, Berlin W. 66, Germany.

Associação dos Engenheiros Civis Portuguezes, Lisbon, Portugal.

Australasian Institute of Mining Engineers, Melbourne, Victoria, Australia.

Boston Society of Civil Engineers, 715 Tremont Temple, Boston, Mass.

Brooklyn Engineers' Club, 117 Remsen Street, Brooklyn, N. Y.

Canadian Society of Civil Engineers, 413 Dorchester Street, West, Montreal, Que., Canada.

Civil Engineers' Society of St. Paul, St. Paul, Minn.

Cleveland Engineering Society, Chamber of Commerce Building, Cleveland, Ohio.

Cleveland Institute of Engineers, Middlesbrough, England.

Dansk Ingeniorforening, Amaliegade 38, Copenhagen, Denmark.

Engineers' and Architects' Club of Louisville, Ky., 303 Norton Building, Fourth and Jefferson Streets, Louisville, Ky.

Engineers' Club of Baltimore, Baltimore, Md.

Engineers' Club of Minneapolis, 17 South Sixth Street, Minneapolis, Minn.

Engineers' Club of Philadelphia, 1317 Spruce Street, Philadelphia, Pa.

Engineers' Club of St. Louis, 3817 Olive Street, St. Louis, Mo.

Engineers' Club of Toronto, 96 King Street, West, Toronto, Ont., Canada.

Engineers' Society of Northeastern Pennsylvania, 415 Washington Avenue, Scranton, Pa.

Engineers' Society of Pennsylvania, 219 Market Street, Harrisburg, Pa.

Engineers' Society of Western Pennsylvania, 2511 Oliver Building, Pittsburgh, Pa.

Institute of Marine Engineers, 58 Romford Road, Stratford, London, E., England.

Institution of Engineers of the River Plate, Buenos Aires, Argentine Republic.

Institution of Naval Architects, 5 Adelphi Terrace, London, W. C., England.

Junior Institution of Engineers, 39 Victoria Street, Westminster, S. W., London, England.

Koninklijk Instituut van Ingenieurs, The Hague, The Netherlands.

Louisiana Engineering Society, 321 Hibernia Bank Building, New Orleans, La.

Memphis Engineering Society, Memphis, Tenn.

Midland Institute of Mining, Civil and Mechanical Engineers, Sheffield, England.

Montana Society of Engineers, Butte, Mont.

North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne, England.

Oesterreichischer Ingenieur- und Architekten-Verein, Eschenbachgasse 9, Vienna, Austria.

Pacific Northwest Society of Engineers, 803 Central Building, Seattle, Wash.

Rochester Engineering Society, Rochester, N. Y.

Sachsischer Ingenieur- und Architekten-Verein, Dresden, Germany.

Sociedad Colombiana de Ingenieros, Bogota, Colombia.

Sociedad de Ingenieros del Peru, Lima, Peru.

Societe des Ingenieurs Civils de France, 19 Rue Blanche, Paris, France.

Society of Engineers, 17 Victoria Street, Westminster, S. W., London, England.

Svenska Teknologforeningen, Brunkebergstorg 18, Stockholm, Sweden.

Tekniske Forening, Vestre Boulevard 18–1, Copenhagen, Denmark.

Western Society of Engineers, 1737 Monadnock Block, Chicago, Ill.

ACCESSIONS TO THE LIBRARY

(From November 3d to December 1st, 1913)

DONATIONS*

SUSPENSION BRIDGES, ARCH RIBS AND CANTILEVERS.

By Wm. H. Burr, M. Am. Soc. C. E. Cloth, $9\frac{1}{4}$ x 6 in., illus., 11 + 417 pp. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Limited, 1913.

The author's aim, it is stated, has been to give in this volume a general treatment of each main structure discussed and to cover, with brevity and clearness, all desired or useful special cases in one demonstration. Such composite structures as are discussed cannot, it is stated, be treated thoroughly without minute analysis, and, therefore, the author has put his formulas in such shape as to make them applicable with the least possible labor, particularly by the aid of the many numerical tables included in the text. These tables, it is hoped, will make the book which, it is said, has been written primarily to meet the author's needs in the class-room, of use also to the practicing engineer. In Chapters IV and V, the author discusses in detail the two prominent methods of analysis for the treatment of stiffened suspension bridges in use at present, namely, the method of Least Work and the method of Deflections, and states that, after full consideration of both methods, the former is at least equally as accurate as the latter, and that its equations are simpler and more easily workable. The Contents are: Suspension Bridges; Statically Indeterminate Stiffening Trusses; Theory of the Straight Stiffening Truss Based on the Method of Deflections; Thermal Stresses; Arch Ribs Treated by Graphical Methods; The General Analytic Theory of Elastic Arch Ribs According to the Law of Least Work; Three-Hinged Arch Rib; Braced Spandrel Arch; Cantilevers; Appendix I, Limiting Spans and Depths of Stiffening Trusses; Appendix II, Formulæ for Reinforced Concrete; Index.

LA RESISTENZA DELLE ARTIGLIERIE:

Nuovi Studi degli Ingegneri Leone Coupaye e Pietro Malaval dell' Artiglieria Navale Francese. Traduzione e Prefazione di Ettore Bravetta, Capitano di Vascello R. N. Paper, 10 x 7 in., illus., 32 + 262 pp. Torino, Carlo Pasta, 1913. 8 lira. (Donated by Comm. Ettore Bravetta.)

In this volume, Captain Bravetta has translated into Italian and brought together in one volume, three essays on the resistance of guns, two of which are by M. Leon Coupaye, and one by M. Peter Malaval, of the French Naval Artillery. The first of M. Coupaye's memoirs, entitled "Notes on the Calculation of the Transversal Structure of Guns," relates to the development of a method for calculating the resistance of guns based on the limitations of the tangential expansions, in which, it is stated, the author discusses, in a comprehensive manner, the elastic limit to be adopted for the elements in each section. In the second work, "Elastic Deformation of the Straight Cylinder; Guns with Purely Elastic Deformations," M. Coupaye, it is stated, has developed the study of the deformation of the straight cylinder, indicating the value of, and the limits of application of, the generic formulas now used. He also discusses methods of calculations for a gun with purely elastic deformations, proving, it is said, that the elastic resistance of a gun is limited by the elasticity of the metals of which it is composed. The third essay, by M. Malaval, relates to investigations and studies as to the deformations of guns beyond the elastic limit of the metal of which they are constructed, in which he demonstrates, it is stated, the possibility of constructing guns capable of supporting enormous pressures without any resulting deformations after the piece returns to a state of repose, which method, it is said, would result in an economy in the cost of workmanship. These essays and the preface are stated to be important contributions on the subject, and to merit the study of all land and naval artillery officers.

SOLUTION OF RAILROAD PROBLEMS BY THE SLIDE RULE.

By E. R. Cary, M. Am. Soc. C. E. Cloth, $6\frac{1}{4}$ x 4 in., illus., 9 + 136 pp. New York, D. Van Nostrand Company, 1913. (Donated by the Author and Publishers.)

The object of this book, as stated in the preface, has been to present, for the convenience of those who have studied railroad curves and the theory of the slide-rule, an easy and rapid method of solving problems in railroad curves by the use

*Unless otherwise specified, books in this list have been donated by the publishers.

of the slide-rule. The Mannheim slide-rule has been used in the solution of these problems, and in order to make the book of more general interest, the author has also included a discussion of the slide-rule, the development of the equations used, a discussion of the easement curves, etc. The Contents are: The Slide Rule; Simple Curves; Compound Curves; Vertical Curves; Turnouts; The Easement Curve; Earthwork; Problems; Diagrams; Tables.

COMPRESSED AIR PRACTICE.

By Frank Richards. Cloth, $9\frac{1}{2}$ x $6\frac{1}{4}$ in., illus., 9 + 326 pp. New York and London, McGraw-Hill Book Company, Inc., 1913. $3.00.

Twenty years ago the author, the preface states, published a book entitled "Compressed Air," parts of which are included in the present volume. The advances made in the industrial status of compressed air and the development of compressed air practice since that time has made it practically necessary, it is said, to rewrite the subject-matter. As the book deals with the general rather than the specific, and is intended for the many rather than the few, the author has included, it is stated, only handy information for those generally who may have to do with compressed air for mechanical and practical uses, its costs, etc., omitting details but suggesting where such details may be found. The Contents are: Atmospheric Generalities; Definitions and General Information; The Compressed-Air Problem; Tables and Diagrams for Computations in Air-Compression; The Indicator on the Air-Compressor; Single-Stage Compression; Two-Stage Air Compression; Two-Stage and Three-Stage Compression; Air Compressor Regulating Devices; The Drive of the Compressor; The Turbo Compressor; The Taylor Compressor—The Humphrey Pump; Power Cost of Compressed Air; Power from Compressed Air; The Air Receiver; Pipe Transmission; Re-heating Compressed Air; Compressor and Receiver Fires and Explosions; Side-Lines for the Air Compressor; Gasoline by Compression—Liquefied Natural Gas; Rock Drill Developments; The Electric Air Drill; Compressed Air for Raising Water; The Air Lift; Air for Large Steam Hammer; Diving Bell and Caisson; Air Jet-Sand Blast-Cement Gun; Liquefied Air—Oxygen from the Atmosphere; Index.

TELEPHONE CABLES:

A Handbook of the Design, Construction, and Maintenance of the Telephone Cable Plant. By J. C. Slippy. Cloth, 7 x $4\frac{1}{2}$ in., illus., 18 + 147 pp. Pittsburgh, Pa., The Author, 1913. $2.50.

The preface states that this work has been compiled with the idea of providing a handbook which would contain, in handy, ready-reference form, the principal data required daily by engineers and others engaged in modern telephone cable-plant layout, installation, and maintenance. The author states that in his endeavor to make the book useful in every-day work, he has omitted many features of telephone cable work and applications which may be found in standard works, and further, that the recommendations and costs contained herein, while representative of the best modern practice, should be followed with proper allowances for local conditions. The Appendix contains data for lead covered dry core cable, wool insulated cable, rubber cable, Okonite cable, messenger wire, splicer's outfit, etc., etc. The Chapter headings are: Cable Specifications; Cable Plans; Cable Construction; Cable Records; Cable for Long Distance Work; Cable Inspection; Cable Troubles and Testing; Cable Costs; Appendix.

HENDRICKS' COMMERCIAL REGISTER OF THE UNITED STATES

For Buyers and Sellers. Twenty-second Annual Edition. Cloth, $10\frac{1}{2}$ x $7\frac{1}{2}$ in., illus., 138 + 1 666 pp. New York, Samuel E. Hendricks Co., 1913. $10.00.

This volume, it is stated in a secondary title, is a complete and reliable annual index devoted to the interests of the architectural, mechanical, engineering, contracting, electrical, railroad, iron, steel, hardware, mining, mill, quarrying, exporting, and kindred industries, and gives more than 350 000 names and addresses, as well as about 55 000 business classifications. It contains, it is stated, full lists of the manufacturers of and dealers in everything used in the manufacture of materials, machinery, and apparatus utilized in the above-mentioned industries from the raw material to the manufactured article, and is said to be indispensable as a buyer's reference and for mailing purposes. The contents are arranged alphabetically by subject, under which are given, in alphabetical order, and, sometimes, by States and cities, the names and addresses of firms dealing in the various articles, and these are followed in some cases by detailed matter, titles of identification, trade names, etc. There is also an alphabetical list of advertisers, including the addresses of their domestic and foreign branches, a simplified discount sheet for the purchasing agent, and an index to contents of 138 pages.

REINFORCED CONCRETE CONSTRUCTION:

Volume II, Retaining Walls and Buildings; Prepared in the Extension Division of the University of Wisconsin. By George A. Hool. (Engineering Education Series.) Cloth, 9½ x 6¼ in., illus., 17 + 666 pp. New York and London, McGraw-Hill Book Company, Inc., 1913. $5.00.

The first volume of this work treats of the fundamental principles of reinforced concrete construction, and in this, the second, volume, as stated in the title, the author discusses in detail the design and construction of retaining walls and buildings, including materials, construction plant, estimates, etc. Like the first volume which, it is said, has been adopted as a textbook in a number of technical schools, the present work is intended for the use of students, but the author hopes that parts of it will prove valuable to engineers in general practice, especially the chapters on Estimating and Construction Plant, which have been written by Messrs. Leslie H. Allen and A. W. Ransome, respectively. The Contents are: Part I, Retaining Walls: Theory of Stability; Design; Construction. Part II, Buildings: Section 1, Design; Floors; Types of Reinforcement; Roofs; Columns; Foundations; Walls and Partitions; Stairs; Elevator Shafts; Provision for Contraction and Expansion; Shear and Moment Considerations in Continuous Beams; Eccentric-Load Considerations in Columns; Wind Stresses; Design of a Factory Building; Example of a Building Design, Including the Specifications. Section 2, Construction: Materials; Forms; Bending and Placing of Reinforcement; Proportioning, Mixing and Placing of Concrete; Finishing Concrete Surfaces; Waterproofing of Concrete; Construction Plant, by A. W. Ransome. Section 3, Estimating, by Leslie H. Allen: Estimating Unit Costs; Estimating Quantities; Example of an Estimate for a Concrete Building; Appendix: Second Report of Joint Committee on Concrete and Reinforced Concrete; Index.

GENERAL SPECIFICATIONS FOR CONCRETE AND REINFORCED CONCRETE

Including Finishing and Waterproofing. By Jerome Cochran, Jun. Am. Soc. C. E. Cloth, 9¼ x 6 in., illus., 23 + 274 pp. New York, D. Van Nostrand Company, 1913. $2.50.

In the preface it is stated that the author's sole purpose in this book has been to produce a set of specifications which will be of increasing influence toward good concrete construction. Many books on the subject have been written and many reports made by committees of various technical societies, but the author states that as there still remain divergent views, not only as to the substance, but also as to the scope, form, and phraseology of such specifications, he hopes this book may prove of value to those engaged in preparing them. The subject-matter is devoted to a detailed discussion of the design and construction of works involving the use of concrete and reinforced concrete, and at the end of each chapter a bibliography of specifications relating to the subject discussed in that chapter is given, the main object of which, it is stated, is to enable the student or young engineer to study the methods used by others in drawing up specifications. The Chapter headings are: Concrete Materials; Proportioning and Mixing Concrete; Forms and Centering; Steel Reinforcement; Transporting and Placing of Concrete; Finishing Concrete Surfaces; Waterproofing Concrete Works; Design of Reinforced Concrete; Reinforced Concrete Building Construction; Appendix A, Suggested Formulas for Reinforced Concrete Construction; Index.

MINE SURVEYING.

By Edward B. Durham. Leather, 7½ x 5 in., illus., 7 + 391 pp. New York and London, McGraw-Hill Book Company, Inc., 1913. $3.50.

The author assumes, it is stated, that the reader is familiar with the ordinary methods of surveying, and, therefore, he includes, in the first chapter, only so much description of general surveying methods and equipment as will establish a common ground for further discussion. In discussing each division of his subjects, the author first gives the principles and general methods of procedure which a student, or an engineer familiar with general surveying, might need in taking up mining work, and these are followed by examples showing variations in practice. The methods described for overcoming difficulties in mine surveying, should be useful, it is said, to practicing engineers as guides in laying out programmes of work for particular problems. Very few of the common surveying instruments are described, it is stated, but descriptions of many special fittings are included, together with illustrations and the names of the manufacturers. Numerous abstracts from articles on related subjects in other publications are included in the text, as well as references to longer articles. The Chapter headings are: General Surveying Methods; Equipment for Underground Surveying; Underground Traversing; Survey-

ing for Details; Traverse Calculations; Maps and Projections; Special Mine Surveys; Special Problems in Mine Surveying; Various Mine Surveying Instruments; Steep Transit Sights; Shaft Plumbing; Tunnel Surveys; Surface and Mine Models; Explanatory Surveys; Magnetic Surveys; Index.

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Cyanide Practice. 1910 to 1913. Edited by M. W. von Bernewitz. Mining and Scientific Press, San Francisco; The Mining Magazine, London, 1913.

Proceedings of the Nineteenth Annual Convention of the American Society of Municipal Improvements, Held at Dallas, Texas, November 12th, 13th, 14th, and 15th, 1912. Williams & Wilkins Company, Baltimore, 1913.

Commission Regulation of Public Utilities: A Compilation and Analysis of Laws of Forty-three States and of the Federal Government for the Regulation by Central Commissions of Railroads and Other Public Utilities. The National Civic Federation, New York, 1913.

Elastische Bogenträger, Einschliesslich der Gewölbe, Eisenbetonbogen und Bogenfachwerke, Ihre Theorie und Berechnung, mit zahlreichen Beispielen und Aufgaben entsprechend den Bedürfnissen der Praxis. Von Jacob J. Weyrauch. Dritte vollständig neubearbeitete Auflage. Konrad Wittwer, Stuttgart, 1911.

Die Eisenkonstruktionen der Ingenieur-Hochbauten: Ein Lehrbuch zum Gebrauche an Technischen Hochschulen und in der Praxis. Von Max Foerster. Ergänzungsband zum Handbuch der Ingenieurwissenschaften. Vierte, verbesserte und stark vermehrte Auflage. 2 Vol. Wilhelm Engelmann, Leipzig, 1909.

Irrigation Works: The Principles on Which Their Design and Working Should be Based, with Special Details Relating to Indian Canals and Some Proposed Improvements. By E. S. Bellasis. Spon & Chamberlain, New York; E. & F. N. Spon, London, 1913.

Das Kabel im Brückenbau. Von F. Hohlfeld. Julius Springer, Berlin, 1913.

Overhead Electric Power Transmission Principles and Calculations. By Alfred Still. McGraw-Hill Book Co., New York and London, 1913.

The Motor and the Dynamo. By James Loring Arnold. The Chemical Publishing Co., Easton, Pa.; Williams & Norgate, London, 1913.

Mitteilungen über Forschungsarbeiten auf dem Gebiete des Ingenieurwesens insbesondere aus den Laboratorien der technischen Hochschulen. Herausgegeben vom Verein deutscher Ingenieure. Hefte 140-142. Julius Springer, Berlin, 1913.

Leitfaden zum Berechnen und Entwerfen von Lüftungs- und Heizungs-Anlagen: Ein Hand- und Lehrbuch für Ingenieure und Architekten. Von H. Rietschel unter Mitwirkung von K. Brabbée. Fünfte, neubearbeitete Auflage. 2 Vol. Julius Springer, Berlin, 1913.

Die Entstehung des Dieselmotors. Von Rudolf Diesel. Julius Springer, Berlin, 1913.

The Year-Book of Wireless Telegraphy and Telephony, 1913. Marconi Press Agency, Ltd. The St. Catherine Press, London.

Die Bergwerksmaschinen. Von Hans Bansen. Erster Band, Das Tiefbohrwesen, von Arthur Gerke und Leo Herwegen; Zweiter Band, Gewinnungsmaschinen, von Arthur Gerke and others. Julius Springer, Berlin, 1912.

Rules of Management, with Practical Instructions on Machine Building. By William Lodge. McGraw-Hill Book Co., Inc., New York and London, 1913.

Der Stadtische Tiefbau. Von E. Schmitt. Band 4, Die Versorgung der Städte mit Leuchtgas, von Moritz Niemann. Arnold Bergsträsser, Stuttgart.

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JUNIORS

BOWEN, EDWARD WITHERS. With Wilbur J. Watson & Co., Commercial National Bank Bldg., Charlotte, N. C.	Nov. 12, 1913
DOWNING, CARL E. Asst. Engr., Belzoni Drainage Comm., Citizens Bank & Trust Co. Bldg., Belzoni, Miss	Oct. 1, 1913

JUNIORS (*Continued*)	Date of Membership.
DURFEE, JOSEPH JAY. Draftsman and Cost Computer, Smith, Hauser, Locher & Co., 25 West 42d St. (Res., 123 Vermilye Ave.), New York City	Nov. 12, 1913
GOODFELLOW, JAMES GORDON. Asst. Engr., Lyttelton Harbour Board, Engr.'s Office, Lyttelton, New Zealand	Sept. 3, 1913
HORAN, HAROLD JOSEPH. Care, U. S. S. *Choctaw*, 1311 Liggett Bldg., St. Louis, Mo	July 2, 1913
JAMES, ROBERT LANE. Asst. Prof., Drawing, Univ. of North Carolina, P. O. Box 267, Chapel Hill, N. C.	Nov. 12, 1913
KELLY, JOHN ARTHUR. Whitney, N. C	June 4, 1913
PEEK, JESSE HOPE. 1421 Arch St., Philadelphia, Pa	Nov. 12, 1913
PIPER, HARRY PAUL, JR. Room 22, Blood Bldg., Amsterdam, N. Y.	Nov. 12, 1913
RUGGLES, WILLIAM WALKER. 4518 Sixteenth Ave., N. E., Seattle, Wash	June 4, 1913

RESIGNATION

ASSOCIATE MEMBER	Date of Resignation.
HAYES, CHARLES EDWARD	Nov. 12, 1913

DEATHS

BANDY, JAMES MARCUS. Elected Associate Member, February 4th, 1903; date of death unknown.

LAKE, ORLOFF. Elected Junior, December 1st, 1908; died October 21st, 1913.

MELLISS, DAVID ERNEST. Elected Member, October 2d, 1895; died March, 1913.

POST, GEORGE BROWNE. Elected Member, September 2d, 1896; died November 28th, 1913.

SNYDER, BAIRD, JR. Elected Member, March 2d, 1904; died July 9th, 1913.

ZIFFER, EMANUEL ALOIS. Elected Member, June 7th, 1893; died October 27th, 1913.

Total Membership of the Society, December 4th, 1913, 7 255.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST

(November 4th to December 1st, 1913)

NOTE.—*This list is published for the purpose of placing before the members of this Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS

In the subjoined list of articles, references are given by the number prefixed to each journal in this list:

(1) *Journal*, Assoc. Eng. Soc., Boston, Mass., 30c.
(2) *Proceedings*, Engrs. Club of Phila., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Chicago, Ill., 50c.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Gesundheits Ingenieur*, München, Germany.
(8) *Stevens Institute Indicator*, Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *Engineering Record*, New York City, 10c.
(15) *Railway Age* Gazette, New York City, 15c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Electric Railway Journal*, New York City, 10c.
(18) *Railway and Engineering Review*, Chicago, Ill., 15c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 20c.
(21) *Railway Engineer*, London, England, 1s. 2d.
(22) *Iron and Coal Trades Review*, London, England, 6d.
(23) *Railway Gazette*, London, England, 6d.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *Railway Age Gazette*, Mechanical Edition, New York City, 20c.
(26) *Electrical Review*, London, England, 4d.
(27) *Electrical World*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal*, Royal Society of Arts, London, England, 6d.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium, 4 fr.
(31) *Annales* de l'Assoc. des Ing. Sortis des Ecoles Spéciales de Gand, Brussels, Belgium, 4 fr.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France, 1 fr.
(34) *Portefeuille Economiques des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(36) *Cornell Civil Engineer*, Ithaca, N. Y.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(39) *Technisches Gemeindeblatt*, Berlin, Germany, 0, 70m.
(40) *Zentralblatt der Bauverwaltung*, Berlin, Germany, 60 pfg.
(41) *Electrotechnische Zeitschrift*, Berlin, Germany.
(42) *Proceedings*, Am. Inst. Elec. Engrs., New York City, $1.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governors Island, New York Harbor, 50c.
(45) *Colliery Engineer*, Scranton, Pa., 25c.
(46) *Scientific American*, New York City, 15c.
(47) *Mechanical Engineer*, Manchester, England, 3d.
(48) *Zeitschrift*, Verein Deutscher Ingenieure, Berlin, Germany, 1, 60m.
(49) *Zeitschrift für Bauwesen*, Berlin, Germany.
(50) *Stahl und Eisen*, Düsseldorf, Germany.
(51) *Deutsche Bauzeitung*, Berlin, Germany.
(52) *Rigasche Industrie-Zeitung*, Riga, Russia, 25 kop.
(53) *Zeitschrift*, Oesterreichischer Ingenieur und Architekten Vereines, Vienna, Austria, 70h.
(54) *Transactions*, Am. Soc. C. E., New York City, $12.

(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $6.
(57) *Colliery Guardian*, London, England, 5d.
(58) *Proceedings*, Engrs.' Soc. W. Pa., 2511 Oliver Bldg., Pittsburgh, Pa., 50c.
(59) *Proceedings*, American Water-Works Assoc., Troy, N. Y.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *Industrial World*, 59 Ninth St., Pittsburgh, Pa., 10c.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 5c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 6d.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England, 6d.
(69) *Der Eisenbau*, Leipzig, Germany.
(71) *Journal*, Iron and Steel Inst., London, England.
(71*a*) *Carnegie Scholarship Memoirs*, Iron and Steel Inst., London, England.
(72) *American Machinist*, New York City, 15c.
(73) *Electrician*, London, England, 18c.
(74) *Transactions*, Inst. of Min. and Metal., London, England.
(75) *Proceedings*, Inst. of Mech. Engrs., London, England.
(76) *Brick*, Chicago, Ill., 10c.
(77) *Journal*, Inst. Elec. Engrs., London, England, 5s.
(78) *Beton und Eisen*, Vienna, Austria, 1, 50m.
(79) *Forscherarbeiten*, Vienna, Austria.
(80) *Tonindustrie Zeitung*, Berlin, Germany.
(81) *Zeitschrift für Architektur und Ingenieurwesen*, Wiesbaden, Germany.
(82) *Mining and Engineering World*, Chicago, Ill., 10c.
(83) *Gas Age*, New York City, 15c.
(84) *Le Ciment*, Paris, France.
(85) *Proceedings*, Am. Ry. Eng. Assoc., Chicago, Ill.
(86) *Engineering-Contracting*, Chicago, Ill., 10c.
(87) *Railway Engineering and Maintenance of Way*, Chicago, Ill., 10c.
(88) *Bulletin* of the International Ry. Congress Assoc., Brussels, Belgium.
(89) *Proceedings*, Am. Soc. for Testing Materials, Philadelphia, Pa., $5.
(90) *Transactions*, Inst. of Naval Archts., London, England.
(91) *Transactions*, Soc. Naval Archts. and Marine Engrs., New York City.
(92) *Bulletin*, Soc. d'Encouragement pour l'Industrie Nationale, Paris, France.
(93) *Revue de Métallurgie*, Paris, France, 4 fr. 50.
(94) *The Boiler Maker*, New York City, 10c.
(95) *International Marine Engineering*, New York City, 20c.
(96) *Canadian Engineer*, Toronto, Ont., Canada, 10c.
(98) *Journal*, Engrs. Soc. Pa., Harrisburg, Pa., 30c.
(99) *Proceedings*, Am. Soc. of Municipal Improvements, New York City, $2.
(100) *Professional Memoirs*, Corps of Engrs., U. S. A., Washington, D. C., 50c.
(101) *Metal Worker*, New York City, 10c.
(102) *Organ für die Fortschritte des Eisenbahnwesens*, Wiesbaden, Germany.
(103) *Mining and Scientific Press*, San Francisco, Cal., 10c.
(104) *The Surveyor and Municipal and County Engineer*, London, England, 6d.
(105) *Metallurgical and Chemical Engineering*, New York City, 25c.
(106) *Transactions*, Inst. of Min. Engrs., London, England, 6s.
(107) *Schweizerische Bauzeitung*, Zürich, Switzerland.
(108) *Southern Machinery*, Atlanta, Ga., 10c.

LIST OF ARTICLES

Bridges.

Fire Resistance Coating for Timber Bridges. (Report of Committee of the Am. Ry. Bridge and Bldg. Assoc.) (87) Nov.
Partial Failure of a Light Highway Bridge.* F. Tissington. (13) Nov. 6.
Shifting the Girders and Columns of the Chicago Elevated Railway.* (13) Nov. 6.
A Gravity Concrete-Depositing Plant, Fallsway Viaduct, Baltimore, Md.* (13) Nov. 6.
Results of Experiments to Determine the Internal Temperature Range in Concrete Arch Bridges.* C. S. Nichols and C. B. McCullough. (Abstract of *Bulletin No. 30*, Eng. Exper. Station, Iowa State Coll. of Agri. and Mechanic Arts.) (86) Nov. 12.
To Get Long Life from Untreated Timber in Trestles. (14) Nov. 15.
Track Elevation at Piqua, Ohio.* (14) Nov. 15.
A Long Concrete Viaduct, Cincinnati. (86) Nov. 19.
New Pontoon Bridge over the Golden Horn at Constantinople.* F. C. Coleman. (13) Nov. 20.

*Illustrated.

Bridges—(Continued).

Bridging the Bosphorus and the Golden Horn at Constantinople.* H. G. Tyrrell. (13) Nov. 20.
Statical Analysis of Reinforced Concrete Arch Bridge.* V. J. Elmont. (96) Nov. 20.
Failure of a Small Highway Bridge by Breaking of a Timber Tension Chord.* (13) Nov. 20.
Methods for the Inspection of Bridges. (15) Nov. 21.
Concrete Pile Specifications (Point Bridge, Pittsburgh). (14) Nov. 22.
Bridges in Relation to the Hudson River. G. F. Kunz. (From Annual Report of the Am. Science and Historic Preservation Soc.) (19) Nov. 29.
Progress of Tunkhannock Viaduct Construction on D., L. & W. Relocation.* (14) Nov. 29.
Constructions en Fonte Revêtue de Beton Fretté, Système von Emperger, Applications aux Ponts en Arc.* (33) Oct. 25.
Schiefe Dreigelenkbogenbrücken aus Eisenbeton.* Walter Nakonz. (49) Pt. 10.
Die neue Kaiser-Wilhelm-Brücke in Trier.* Schilling. (40) Oct. 18.

Electrical.

The Efficiency of the Polyphase Induction Motor from the Current (Circle) Diagram; Together with an Equation Connecting the Output and Input of the General Electric Circuit.* J. S. Nicholson. (77) Oct.
New Alternating-Current Compensation Apparatus for Telephonic Measurements.* A. K. Erlang. (77) Oct.
Time-Limit Elements.* H. R. Constantine. (77) Oct.
The Phasing-Out of Alternating-Current Apparatus.* J. Hacking. (77) Oct.
Low and Mixed Pressure Turbine Plant.* C. H. Goulden. (77) Oct.
The Heating and Cooling of Electrical Machinery.* P. Grice. (77) Oct.
Winding of Electrical Machinery.* A. T. Robertson. (77) Oct.
Individual Electric Drive in Modern Weaving Sheds.* S. N. C. K. Whitehead. (77) Oct.
Application of Mechanical Devices to the Assistance of Manual Operating in Telephone Exchanges.* W. Slingo. (77) Oct.
Application of Wireless Telegraphy to Time Signals. G. A. Ferrie. (77) Oct.
Petro-Electric Motor Vehicles. J. B. G. Damoiseau. (77) Oct.
The Transmission of Electrical Energy by Continuous Current on the Series System.* J. S. Highfield. (77) Oct.
Electric Transmission of Energy by Alternating Currents at Very High Pressures.* Maurice Leblanc. (77) Oct.
Central Power Station Working. G. M. Robertson. (Abstract of paper read before the South African Inst. of Engrs.) (47) Oct. 31.
Tests on Induction Motors Designed with Deep Rotor Slots.* L. D. Jones. (Abstract from *General Electric Review.*) (73) Oct. 31.
The Municipal Lighting Plant at Seattle, Wash.* J. D. Ross. (60) Nov.
Hydro-Electric Power in Mexico.* W. D. Hornaday. (82) Nov. 1.
The 25 000-Kw. Turbine for Fisk Street.* (64) Serial beginning Nov. 4.
The Kathode-Ray Oscillograph and Its Uses. H. H. Broughton. (73) Nov. 7.
Compensated Alternating Current Generators.* (12) Nov. 7.
100 000-Volt Transmission into Bombay, India.* (27) Nov. 8.
A Norwegian Hydro-Electric Plant.* (26) Nov. 14.
Electric Power from Fuel at Mines.* Geo. E. Edwards. (82) Nov. 15.
Hydroelectric Development on the Tennessee River.* (27) Nov. 15.
Industrial Lighting by Incandescent Lamps.* (27) Nov. 15.
Effective Resistance and Reactance.* Waldo V. Lyon. (27) Nov. 15.
Comparison of Lead-Sulphuric and Edison Types of Storage Battery.* Eugene Oster. (64) Nov. 18.
Notes on Electric Furnaces, with Special Reference to an Induction Furnace. W. Glucksman. (Paper read before the South African Inst. of Elec. Engrs.) (96) Nov. 20.
A Method of Predetermining the Effect of Field Distortion in Continuous-Current Generators. Alfred Hay. (73) Nov. 21.
The Audion-Detector and Amplifier.* Lee De Forest. (Paper read before the Inst. of Radio Engrs.) (73) Nov. 21.
Progress of Drum Development of Pacific Gas & Electric Company.* F. G. Mudgett. (27) Nov. 22.
Combined Synchronous and Induction Motor Loads. H. L. Wallau. (27) Nov. 22.
South Yuba-Bear River Power Development.* J. P. Jollyman. (14) Nov. 22.
A Radical Improvement in Cabling.* Herbert T. Wade. (46) Nov. 22.
Elverum Hydroelectric Development.* (14) Nov. 22.
Condition of Experimental Telegraph Poles, Treated and Untreated, after Eight Years Service.* C. H. Teesdale. (13) Nov. 27.
New Turbine Installation at Little Rock, Ark.* (27) Nov. 29.
Armature Mmf. Relations in Synchronous Machines.* J. H. Morecroft. (27) Nov. 29.

*Illustrated.

Electrical—(Continued).

Ueber den Einfluss von Kompensationsdrosselspulen auf die Betriebsverhältnisse in Hochspannungs-Kabelleitungen. J. Kühle. (41) June 26.
Technische Einrichtung und Betrieb der neuen Fernsprechvermittlungsstelle "Wilhelm" in Charlottenburg b. Berlin.* K. Buttler. (41) Serial beginning June 26.
Die Herstellung moderner Metallfadenlampen. Otto Ruff. (48) Oct. 11.
Erdungen zur Erreichung eines hohen Schutzwertes.* S. Ruppel. (41) Oct. 23.
Ein neues Verfahren zur Löschung des elektrischen Lichtbogens und seine Anwendung auf Schalter und Unterbrecher.* W. Burstyn. (41) Oct. 23.
Eine Selbsterregererscheinung bei einem Drehstrom-Riehenschluss-Kollektormotor mit sechs Bürsten.* Scherbius und C. E. Sonnenschein. (41) Oct. 23.
Die Nutzbarmachung der Wasserkräfte der oberen Rhone für elektrische Energieübertragung nach Paris.* (41) Oct. 23.
Selbsttätiger und handbedienter Fernsprechbetrieb. Victor J. Baumann. (41) Nov. 6.
Theorie der dielektrischen Nachwirkung.* Karl Willy Wagner. (41) Nov. 6.
Die Wähleranzahl in automatischen Fernsprechämtern, ein theoretische Untersuchung.* P. V. Christensen. (41) Nov. 13.
Hitzbeständige Elektromagnetspulen.* B. Duschnitz. (41) Nov. 20.
Selbsterregung gesättigter Mehrphasen-Kollektor-Reihenschlussmaschinen.* A. Scherbius. (41) Nov. 21.

Marine.

On the Maximum Dimension of Ships. William H. White. (91) Vol. 19.
The Raising of the Dry-Dock *Dewey*.* L. S. Adams. (91) Vol. 19.
Economy in the Use of Oil as Fuel for Harbor Vessels.* C. A. McAllister. (91) Vol. 19.
The Best Arrangement for Combined Reciprocating and Turbine Engines on Steamships.* G. W. Dickie. (91) Vol. 19.
The Parsons Marine Steam Turbine and Its Application to Various Classes of Vessels.* E. H. B. Anderson. (91) Vol. 19.
Heavy-Oil Engines for Marine Propulsion.* G. C. Davison. (91) Vol. 19.
Automatic Record of Propeller Action in an Electrically Propelled Vessel.* W. L. R. Emmet. (91) Vol. 19.
Ship Calculations; Derivation and Analysis of Methods.* T. G. Roberts. (91) Vol. 19.
Some Model Basin Investigations of the Influence of Form of Ships Upon Their Resistance.* D. W. Taylor. (91) Vol. 19.
The Resistance of Some Merchant Ship Types in Shallow Water.* Herbert C. Sadler. (91) Vol. 19.
Experiments on the *Froude*.* C. H. Peabody. (91) Vol. 19.
The Effect of Waves Upon a Taffrail Log.* Harold A. Everett. (91) Vol. 19.
Notes on Life-Saving Appliances.* W. D. Forbes. (91) Vol. 20.
The Preservation of Metals Used in Marine Construction. Frank Lyon. (91) Vol. 20.
An Electrically Propelled Fireproof Passenger Steamer.* William T. Donnelly and George A. Orrok. (91) Vol. 20.
Active Type of Stabilizing Gyro.* Elmer A. Sperry. (91) Vol. 20.
Notes on Fuel Economy as Influenced by Ship Design.* E. H. Rigg. (91) Vol. 20.
Developments in Oil Burning.* E. H. Peabody. (91) Vol. 20.
The Sperry Gyro-Compass in Service.* R. E. Gillmor. (91) Vol. 20.
Experiments on the *Fulton* and the *Froude*.* C. H. Peabody. (91) Vol. 20.
The Design and New Construction Division of the Bureau of Construction and Repair of the Navy Department.* R. H. Robinson. (91) Vol. 20.
Engineering Progress in the U. S. Navy.* C. W. Dyson. (91) Vol. 20.
Rudder Trials U. S. S. *Sterett*.* R. T. Hanson and J. C. Hunsaker. (91) Vol. 20.
Logarithmic Speed-Power Diagram.* Thomas M. Gunn. (91) Vol. 20.
Tool Steel for the United States Navy.* Lewis Hobart Kenney. (91) Vol. 20.
A New Mounting for Big Naval Guns.* (12) Oct. 31.
The Fried. Krupp Germania Ship Building Yard, Kiel.* (11) Nov. 7.
The Fire Control Platform of a United States Battleship. J. Bernard Walker. (46) Nov. 8.
The H. M. S. *Benhow;* A Twenty-Five Years Retrospect. (11) Nov. 14.
Connecticut State Steamship Terminals. (86) Nov. 19.
Steam Propelling Machinery for Small Vessels.* (11) Nov. 21.
The Greatest Side-Wheel Steamer Afloat, the *Seeandbee*.* (46) Nov. 29.
La Question des Docks Flottants.* H. Chaumonot. (92) Aug.
Les Paquebots *Paul-Lecat* et *André-Lebon* de la Compagnie des Messageries Maritimes.* Gownèt. (33) Nov. 15.
Ueber die Verwendung von Schleppkatzen und Spillen beim Verholen der Schiffe.* Möller. (40) Oct. 15.

*Illustrated.

Marine—(Continued).

G. Seebeck A. G., Schiffswerft, Maschinenfabrik und Kesselschmiede in Geestemünde.* Fr. Muller. (48) Oct. 18.
Die Beanspruchung der Beschaufelung von Schiffsturbinen durch dynamische Wirkungen und ihre Beziehungen zum Schaufelsalat.* Schumacher. (48) Oct. 18.

Mechanical.

Some Applications of the Principles of Naval Architecture to Aeronautics.* William McEntee. (91) Vol. 19.
Neon Lighting. Georges Claude. (77) Oct.
Spherical Balloons.* R. H. Upson. (8) Oct.
Depreciation; Estimated and Actual. Alex. C. Humphreys. (Paper read before the Institution of Gas Engrs.) (8) Oct.
The Development of the Use of Gas for Industrial Purposes. H. M. Thornton. (Paper read before the British Commercial Gas Assoc.) (66) Oct. 28.
Aeronautics.* J. E. Petavel. (29) Serial beginning Oct. 31.
Large Prime Movers and Boilers for Power Houses.* E. Kilburn Scott, A. M. Inst. C. E. (Paper read before the National Assoc. of Colliery Mgrs.) (22) Oct. 31.
Modern By-Product Coking.* G. S. Cooper. (Paper read before the Junior Institution of Engrs.) (57) Oct. 31.
Machine Tools for the Production of Worm Gears.* (12) Serial beginning Oct. 31.
A Design for a Portland Cement Plant with a Car System for Transporting Materials.* C. J. Tomlinson. (67) Nov.
Dynamo Electric Lighting for Motor Cars. Alfred E. Waller. (42) Nov.
Advantages of Clutch Type Generator and Separate Starting and Lighting Units for Motor Cars.* Alexander Churchward. (42) Nov.
Electrical Equipment of Gasoline Automobiles.* Frank Conrad. (42) Nov.
Symposium of the Automobile Motor.* J. B. Entz. (From *Transactions*, Cleveland Eng. Soc.) (108) Nov.
The Abatement of Locomotive Smoke. D. F. Crawford. (Paper read before the Inter. Soc. for the Prevention of Smoke.) (18) Nov. 1.
Herringbone Gears for Steel Mills.* P. C. Day. (Abstract of paper read before the Iron and Steel Elec. Engrs.) (62) Nov. 3.
Oil Gas.* L. B. Jones. (Paper read before the Pacific Coast Gas Assoc.) (24) Nov. 3.
The Continuous Kiln, How to Increase Daily Capacity 100 per cent.* William A. Butler. (76) Nov. 4.
A Manufacturer's Hydraulic Laboratory.* P. A. Bancel. (13) Nov. 6.
Handling Materials by Bucket Carriers.* Reginald Trautschold. (96) Nov. 6.
The 33 500-Hp. British-Built Steam Turbine of the Commonwealth Edison Co., Chicago.* (13) Nov. 6.
A Cableway for Railway Lumber Cars.* M. M. Cooke. (13) Nov. 6.
Empirical Design of Stationary Gas-Engine Pistons.* G. W. Lewis. (72) Nov. 6.
Heat-Treated Gears in Machine Tools.* Andrew C. Gleason. (Paper read before the National Machine Tool Builders' Assoc.) (72) Nov. 13; (20) Nov. 6.
Some Boiler Defects and Their Causes.* F. W. Sisson. (Abstract of paper read before the Nottingham Eng. Soc.) (47) Nov. 7.
Motor Car Show at Olympia.* (12) Nov. 7; (11) Oct. 31.
Boiler and Economiser Efficiency and Design. Robert H. Smith. (12) Nov. 7.
Solving the Fuel Problem for the Motor Truck.* Harold Whiting Slauson. (From *Machinery*.) (19) Nov. 8.
Ball Bearings; Their Construction and Application.* F. H. Poor. (From *Machinery*.) (19) Nov. 8.
Liquid Purification of Coal Gas.* James G. O'Neill. (Paper read before the Am. Gas Inst.) (24) Nov. 10; (83) Dec. 1.
Standards of Quality and Pressure of Oil Gas. W. H. Papst. (Paper read before the Pacific Coast Gas Assoc.) (24) Nov. 10; (83) Dec. 1.
Best Vacuum with a Cooling Tower.* Paul A. Bancel. (64) Nov. 11.
Steam Regenerative Accumulators.* H. Fothergill. (64) Nov. 11.
Gas Supply to Outlying Villages.* W. M. Valon. (Paper read before the Midland Assoc. of Gas Engrs. and Mgrs.) (66) Nov. 11.
The Gas-Fire.* Harold Hartley. (Paper read before the Junior Gas Assoc.) (66) Nov. 11.
Improved Management and Reduction of Construction and Operation Costs Following Introduction of Automobiles in the San Francisco Gas Distribution Department. D. E. Keppelmann. (Paper read before the Pacific Coast Gas Assoc.) (86) Nov. 12; (83) Nov. 15.
The Insulation of Furnaces.* Chas. R. Darling. (11) Nov. 14.
7 000-Kilowatt Steam-Turbine at the Tramway Power-Station, Sydney, N. S. W.* (11) Nov. 14.

*Illustrated.

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Coal Washing, Coke and By-Product Plant at Baruch.* (57) Nov. 14.
Steam Boiler Working in Electrical Power Stations. J. W. Jackson. (Abstract of paper read at Newcastle.) (73) Nov. 14.
Powdered Coal as Fuel. W. S. Quigley. (Paper read before the Am. Foundrymen's Assoc.) (18) Nov. 15.
The Behavior of Water in Holder Cups and Tanks.* Herbert W. Alrich. (Paper read before the Am. Gas Inst.) (24) Nov. 17.
A Survey of the Gas-Fire Position. H. James Yates. (Paper read before the Manchester and District Junior Gas Assoc.) (66) Nov. 18.
Carbonization of Coal in Vertical Retorts. O. B. Evans. (Paper read before the Am. Gas Inst.) (66) Nov. 18.
Flatbush Gas-Electric Station.* Charles H. Bromley. (64) Nov. 18.
A Cableway with Side-Swinging Towers.* (13) Nov. 20.
A System for Storing and Handling Inflammable Liquids.* (13) Nov. 20.
Carbonization of Shafting.* Jay G. Weiss. (Abstract of paper read before the National Machine Tool Builders Assoc.) (72) Nov. 20.
The Adoption of Fuel Oil.* (96) Nov. 20.
Heat Treated Gears in Machine Tools.* J. Heber Parker. (Paper read before the National Machine Tool Builders Assoc.) (20) Nov. 20.
Skip-Hoists.* Reginald Trautschold. (96) Nov. 20.
The Lackawanna Frog and Switch Shops.* (15) Nov. 21.
The German Aeroplane Motor Competition.* W. Landahn. (From the *Marine-Rundschau.*) (12) Serial beginning Nov. 21.
The Stability of Gyroscopic Single Track Vehicles.* H. Cousins, A. M. Inst C. E. (11) Serial beginning Nov. 21.
Heavy Oil as Fuel for Internal Combustion Engines. Irving C. Allen. (From *Industrial Engineering and Engineering Digest.*) (19) Nov. 22.
Steam Flow Meters. Irving B. Terry. (Paper read before the Ohio Soc. of Mech., Elec. and Steam Engrs.) (62) Nov. 24.
Automatic Furnace Hoists at Monessen, Pa.* (20) Nov. 27.
On the Relative Value of Foundry Flour with Simple Methods of Testing.* G. S. Evans. (Paper read before the Am. Foundrymen's Assoc.) (62) Dec. 1.
Gas Rates. Alten S. Miller. (Paper read before the Am. Gas Inst.) (83) Dec. 1.
Armure à Lames pour le Sciage des Pierres de Taille.* A. Nachtergal. (34) Nov.
Four Continu pour la Cuisson des Chaux et Ciments.* (35) Nov.
Moteurs Diesels-Carels de 2 200 Chevaux et de 1 000 Chevaux.* Ch. Dantin. (33) Nov. 8.
Le Programme de l'Epreuve d'Endurance des Carnious Militaires pour 1914. D. Duaner. (33) Nov. 8.
Les Véhicules Industriels au Salon de l'Automobile.* D. Duaner. (33) Nov. 15.
Ueber Treiböle.* E. J. Constam and P. Schläpfer. (48) Serial beginning Sept. 20.
Die Förderanlagen der Speicherei- und Speditions-A-G. Dresden-Riesa.* W. Spielvogel. (48) Sept. 20.
Neue Kaskaden-Motoren, Bauart Sandycroft-Hunt.* A. Ricker. (48) Sept. 20.
Zeichnerische Ermittlung von Stufenrädergetrieben.* Rudolf Langner. (48) Sept. 27.
Schmauchen mit Luft. H. Sochse. (80) Oct. 16.
Das Stahlwerk Julienhütte und das Elektrostahlwerk Baildonhütte.* (50) Serial beginning Oct. 23.
Die neuesten Fortschritte deutscher Helling-Förderanlagen.* Otto Lienau. (48) Oct. 25.
Versuche über den Wirkungsgrad von Seilen.* H. Bonte. (48) Oct. 25.
Die Entwicklung der Oerlikon-Dampfturbine.* J. Karrer. (48) Oct. 28.
Ueber neuere Trockenkammern mit besonderer Berücksichtigung der Amerikanischen.* Eugen Munk. (50) Oct. 30.
Hochbau-Montagen.* Joester. (69) Nov.
Selbstkostenermittlung bei elektrischen Kraftanlagen auf Hüttenwerken.* D. Paul Schoenfeld. (50) Nov. 6.
Berechnung eines Maschinenkellers aus Eisenbeton.* H. Winkelmann. (78) Nov. 7.
Zur Beurteilung der Bone-Schnabel-Kessel. G. Neumann. (50) Nov. 20.

Metallurgical.

The Herreshoff Roasting Furnace.* (103) Nov. 1.
The Open-Hearth Furnaces at Midland, Pa.* (20) Nov. 6.
The Metals and Alloys Used in Engineering Practice. George Hailstone. (Paper read before the Handsworth Eng. Soc.) (47) Nov. 7.
Influence of Phosphorus on Some Copper-Aluminum Alloys.* A. A. Read. (Paper read before the Inst. of Metals.) (47) Nov. 7.
Lead, Zinc and Copper Smelting in America.* (16) Serial beginning Nov. 8.

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Metallurgical—(Continued).

An Excursion to North American Smelting Works. Ferdinand Heberlein. (Paper read before the Gesellschaft deutscher Metallhütten und Bergleute.) (103) Nov. 8.
The Treatment of Blast Furnace Flue Dust. Eugene B. Clark. (Paper read before the Am. Iron and Steel Assoc.) (20) Nov. 13.
Zinc Smelting in the Electric Furnace.* Woolsey McA. Johnson. (16) Nov. 22.
Witherbee Sherman No. 3 Magnetic Mill.* S. L. Nason. (16) Nov. 22.
Foundry Experiences with Semi-Steel Mixtures. R. Hastings Probert. (Paper read before the Ohio Mech., Elec. and Steam Engrs.) (62) Nov. 24.
Du Rôle de l'Arsenic dans les Cuivres Industriels.* P. Jolibois et P. Thomas. (93) Nov.
Recherches sur les Alliages de Manganèse et d'Argent.* G. Arrivaut. (93) Nov.
Ueber neuere Verfahren zur Erzielen dichter Flusseisenblöcke.* C. Canaris. (50) Nov. 13.
Ueber die Wirtschaftlichkeit von Hochofenbegichtungsanlagen. F. Lilge. (50) Serial beginning Nov. 13.

Mining.

Removal of a Shaft-Pillar at South Kirby Colliery.* Charles Snow. (Paper read before the Midland Inst. of Min., Civ. and Mech. Engrs.) (106) Vol. 46, Pt. 1.
The Coal-Fields and the Coal-Industry of Eastern Canada.* Francis William Gray. (Paper read before the Midland Inst. of Min., Civ. and Mech. Engrs.) (106) Vol. 46, Pt. 1.
Examples of the Use of Concrete at Collieries.* John Gregory. (Paper read before the North Staffordshire Inst. of Min. and Mech. Engrs.) (106) Vol. 46, Pt. 1.
Notes on Coal Mining in the United States of America, with Special Reference to the Treatment of Coal-Dust, and Haulage by Electric Locomotives.* Samuel Dean. (Paper read before the North of England Inst. of Min. and Mech. Engrs.) (106) Vol. 46, Pt. 1.
The Comparative Inflammability of Mixtures of Pit-Gas and Air, Ignited by Momentary Electric Arcs. W. M. Thornton. (Paper read before the North of England Inst. of Min. and Mech. Engrs.) (106) Vol. 46, Pt. 1.
Lead Mines and Works of the Vieille Montagne Zinc Company. (106) Vol. 46, Pt. 1.
Miners' Nystagmus and Its Effect on Vision. J. Court. (Paper read before the Midland Inst. of Min., Civ. and Mech. Engrs.) (106) Vol. 46, Pt. 1.
Electric-Winding Plant at South Kenmuir Colliery.* Willoughby M. Dunn. (Paper read before the Midland Inst. of Min., Civ. and Mech. Engrs.) (106) Vol. 46, Pt. 1.
Mine Fires and the Application of Oxygen Breathing Apparatus to Their Direct Attack. Edwin M. Chance. (98) Sept.
The Sinking and Lining of Shafts.* Francis Donaldson. (2) Oct.
French Coaldust Experiments at Commentry.* J. Taffanel. (57) Oct. 31.
Mine Humidification.* Dwight Gerber. (45) Nov.
The Cementation Process for Sinking Shafts. Sydney F. Walker. (45) Nov.
Ventilation of the Mines of the Rand. G. H. Blenkinsop. (Paper read before the Chemical, Metallurgical and Min. Soc. of South Africa.) (68) Nov. 1.
A Free Piston Gasoline Rock Drill.* (13) Nov. 6.
Electrical Plant at the Aberpergwm Collieries.* (22) Nov. 7.
Advantages of Oval over Circular Pipes for Hydraulic Gob Stowing. O. Putz. (22) Nov. 7.
A Novel Firedamp Indicator.* F. Haber. (Paper read before the Kaiser-Wilhelm-Institut.) (57) Nov. 7.
The Magnetite Mines near Port Henry, N. Y.* L. O. Kellogg. (16) Nov. 8.
Resoiling After Dredging in California.* G. L. Hurst. (103) Nov. 8.
Steel Ore Passes at Broken Hill. John M. Bridge. (Paper read before the Australian Inst. of Min. Engrs.) (103) Nov. 15.
The Tangshan Colliery, North China.* H. Chatley and H. T. Wright. (12) Nov. 21.
Electric Winding Engines for Colliery.* (57) Nov. 21.
The Fire at the Cadder Colliery.* Henry Cunynghame. (57) Nov. 21.
Ashington and Ellington Collieries.* J. J. Hall and F. L. Booth. (22) Serial beginning Nov. 21.
Stoping Methods at the North Star Mine.* L. O. Kellogg. (16) Nov. 29.
Laying Out Cananea Underground Curves.* A. Carr Harris. (16) Nov. 29.

Miscellaneous.

The Relation of the Engineer to Public Improvements. John A. Bensel, M. Am. Soc. C. E. (Paper read before the Clarkson School of Technology.) (8) Oct.
Coöperation among Engineering Societies. Ralph D. Mershon. (4) Oct.
Engineering as a Profession. Walter J. Francis. (96) Nov. 6.

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The Panama-Pacific Exposition.* A. H. Markwart. (13) Serial beginning Nov. 6.
Provincial Public Works Organization of the Philippine Islands and Its Engineering Personnel.* (13) Nov. 13.
Some General Principles Applicable to Public Construction Contracts. (13) Nov. 20.
Some Phases of the Illumination of Interiors.* Preston S. Miller. (Paper read before the Illuminating Eng. Soc.) (19) Nov. 22.
Die Kennzeichnung der Farbe des Lichtes.* L. Bloch. (41) Nov. 13.

Municipal.

Some Aspects of the Road Question.* William Calder. (Paper read before the Farmers' Convention.) (104) Oct. 31.
Brick Paving for Country Roads.* Vernon M. Peirce and Charles H. Moorefield. (9) Nov.; (96) Nov. 20.
Reinforced Concrete Paving at Port Huron, Mich.* Earle R. Whitmore. (67) Nov.
Gravel and Stone Qualities, Tests and Selections.* A. T. Goldbeck. (Paper read before the Am. Road Congress.) (67) Nov.
A New Automatic Fire Alarm.* F. A. Fitzgerald. (3) Nov.
Development and Maintenance of Highways in Allegheny County, Pennsylvania.* John S. Gillespie. (Paper read before the Am. Highway Assoc.) (60) Nov.
Detroit's Municipal Asphalt Plant.* H. B. Pullar. (60) Nov.
Concrete Roads, an Article Based Upon Two Separate Reports.* Frank F. Rogers and P. E. Green. (60) Nov.
Top Dressing for Concrete Pavements in Grand Haven, Mich. W. J. Sherman Co. (36) Nov.
Legal Suggestions Respecting Road Contracts. William Law Bowman. (36) Nov.
A City Built to Order, Construction Work Planned and in Progress for the Industrial City of Kincaid, Illinois.* (86) Nov. 5.
The Protection and Upkeep of Road Equipment. Daniel J. Haner. (Paper read before the Am. Road Congress.) (96) Nov. 6.
Tar-Macadam Road Construction and Cost at Bridlington.* Ernest R. Matthews, Assoc. M. Inst. C. E. (11) Nov. 7.
Earth and Sand Clay Roads.* (From *Bulletin 47*, Office of Public Roads.) (19) Nov. 8.
Paved Roads and Road-Laying Machinery.* (From *Bulletin 47*, Office of Public Roads.) (19) Nov. 8.
Tar for Roads.* C. H. Webb. (Paper read before the Midland Gas Assoc.) (66) Nov. 11.
Value of the Fixed Carbon Test (as Applied to Bituminous Materials). H. B. Pullar. (96) Nov. 13.
Discussion on Concrete Roads. A. N. Johnson. (96) Nov. 13.
New York State Road Organization. George C. Diehl, Harold Parker, and William DeH. Washington. (13) Nov. 13.
Care of Streets in Chicago. (14) Nov. 15.
Pavement Construction with Bricks Laid Flatwise or with the Fiber in a Vertical Position. James T. Tucker. (86) Nov. 19.
Motor-Omnibus Operation in New York City. (13) Serial beginning Nov. 20.
Gravel Roads—Construction and Maintenance. S. Percy Hooker. (Abstract of paper presented at Third Am. Road Congress.) (14) Nov. 22.
Wood Block on Steep Grades. (14) Nov. 22.
Methods and Cost of Constructing a Concrete Road near Mason City, Iowa.* (86) Nov. 26.
A Vertical Tank Paving Block Creosoting Plant.* (86) Nov. 26.
Adaptability and Economy of Motor Trucks in Hauling Garbage and Street Repair Materials in Chicago.* (86) Nov. 26.
Die baugeschichtlichen Grundlagen des Karlsruher Stadtplans.* A. E. Brinckmann. (49) Pt. 10.
Ueber Eckgrundstücke. Moser. (39) Serial beginning Oct. 20.
Der Bebauungsplan für das Bruderholz in Basel.* (107) Serial beginning Oct. 25.
Sicherung unterhöhlter Strassendecken.* Julius Barth. (80) Oct. 30.
Zur Frage der Staubbekampfung in Stadtstrassen. D. Scheuermann. (39) Nov. 5.

Railroads.

Electric Locomotives.* F. Lydall. (77) Oct.
Railway Electrification Problems in the United States.* H. Parodi. (77) Oct.
The Electrification Schemes of the Chemins de Fer du Midi.* E. J. Julian. (77) Oct.
The Electrification of the State Railway: the Paris Suburban Lines. A. N. Mazen. (77) Oct.

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Railroads—(Continued).

Application of Concrete in the Abolishment of Grade Crossings, Philadelphia, Pa., 1912.* Jas. W. Phillips. (Abstract of paper read before the National Assoc. of Cement Users.) (87) Nov.
The Indirect Results of National Railway Valuation. J. Shirley Eaton. (9) Nov.
Billerica Shops, Boston & Maine R. R.* (87) Nov.
Cattle Guards. (Report of Committee of the Am. Ry. Bridge and Bldg. Assoc.) (87) Nov.
Electrification of the Melbourne Suburban Railways.* E. Vytborck. (88) Nov.
Goods Train Brake Trials on the Paris-Lyons-Mediterranean Railway. A. Huberti. (88) Nov.
Wooden Sleepers or Iron Sleepers. Waas and Biedermann. (From *Zeitung* des Vereins deutscher Eisenbahnverwaltungen.) (88) Nov.
The Traffic-Capacity of Terminus Stations for Urban and Suburban Traffic.* G. Brecht. (From *Elektrische Kraftbetriebe und Bahnen.*) (88) Nov.
Carriage by Water and by Rail. G. Renaud and C. Colson. (From *Revue politique et parlementaire.*) (88) Nov.
Superheated Locomotives. P. C. Linck. (Paper read before the Inter. Ry. General Foremens' Assoc.) (94) Nov.
Safety First.* L. R. Davis. (Paper read before the Southern and Southwestern Ry. Club.) (108) Nov.
Cost of Maintenance of the Rapid Acting Vacuum Brake on the Halberstadt-Blankenburg Railway. Glanz. (From *Glaser's Annalen für Gewerbe und Bauwesen.*) (21) Nov.
New 4-4-0 Express Engines, Great Central Railway.* (21) Nov.
New Corridor Trains, L. & North-Western and Caledonian Railways.* (21) Nov.
4-8-2 Type Locomotives for Missouri Pacific.* (25) Nov.
Design of Locomotive Grates.* W. R. Hedeman. (25) Nov.
Sulzer-Diesel Locomotive. (25) Nov.
Cumberland Terminal of the B. & O.* R. C. Powers. (25) Nov.
Engine House Organization and Operation.* W. Smith. (Paper read before the Ry. General Foremens' Assoc.) (25) Nov.
Wabash 60-Foot Steel Postal Car.* (25) Nov.
Special Baggage Car for Scenery.* (25) Nov.
The Standard Locomotive Stoker.* (25) Nov.
Electrical Equipment for Railroad Shops.* J. H. Bryan. (108) Nov.
Round House Design and Equipment.* Park A. Dallis. (108) Nov.
Rhine High-Tension Direct-Current Railways.* (17) Nov. 1.
New Dessau-Bitterfeld Locomotive.* (17) Nov. 1.
Service Records of Vanadium Steel Main and Side Rods. (18) Nov. 1.
Mountain Type Locomotives for the Missouri Pacific Ry.* (18) Nov. 1.
Report on the Stilwell Derailment, C., C., C. & St. Louis Ry.* (18) Nov. 1.
Proposed Compound Switching Locomotive.* (18) Nov. 1.
Gasoline-Electric Train Unit for Egyptian Railways.* (18) Nov. 1.
The Abatement of Locomotive Smoke. D. F. Crawford. (Paper read before the Inter. Soc. for the Prevention of Smoke.) (18) Nov. 1.
The Leonard Locomotive and Car Shops of the National Transcontinental Railway at Quebec, P. Q.* (96) Nov. 6.
Narrow Gauge Passenger Locomotives for South Africa.* (12) Nov. 7.
Electrification of the L. & S. W. Railway's Suburban Lines.* (12) Nov. 7.
Construction of Clinchfield Extension: Building a 35-Mile Line over the Cumberland Range.* (15) Nov. 7.
Locomotive Fuel Economy on the Frisco.* Robert Collett. (Abstract of paper presented before the St. Louis Ry. Club.) (15) Nov. 7.
Diesel Locomotive for Prussian-Hessian State Railways.* (17) Nov. 8.
New Locomotive Repair Plant, Wabash R. R., Decatur, Ill.* (18) Nov. 8.
Six More Powerful Electric Locomotives for the New York Central Terminal.* (18) Nov. 8.
The Jungfrau Railway.* (46) Nov. 8.
Some Problems Involved in Driving Long and Deeply Overlaid Tunnels.* E. Lauchli. (14) Nov. 8.
A Costly Terminal and Track Elevation Work. Plans for Railway Relocation and Track Elevation and New Water Terminals at South Philadelphia, Pa.* (86) Nov. 12.
Life of Physical Railway Property. (Abstract of Report of the Joint Committee on Life of Railway Physical Property of the Am. Elec. Ry. Eng. and Accountants Assoc.) (13) Nov. 13.
Tunnel Construction on the Willamette Pacific R. R. (13) Nov. 13.
Summit-Hallstead Cut-Off of D., L. & W.* (15) Serial beginning Nov. 14.
Overloading Freight Locomotives not Economical. J. S. Sheafe. (15) Nov. 14.
Gas-Electric Locomotive.* (15) Nov. 14.
Movement of Prices and Railway Rates. Clement Colson. (15) Nov. 14.
Approximate Predetermination of Train Energy. W. A. Del Mar and D. C. Woodbury. (17) Nov. 15.

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The 2 500-Hp. Lötschberg Locomotives.* (17) Nov. 15; (12) Nov. 21.
Electric Locomotives for Swiss Railway.* (27) Nov. 15.
Resurvey of the Wheeling & Lake Erie R. R.* (18) Nov. 15.
A Suspension Dumping Bridge for Building Railway Embankment.* (13) Nov. 20.
A Rail-Handling Machine for Rail Renewals.* (13) Nov. 20.
The Lackawanna Frog and Switch Shops.* (15) Nov. 21.
Internal-Combustion Motors for Railways.* F. W. Lanchester. (Paper read before the Eng. Section of the British Assoc.) (11) Nov. 21.
Steel Passenger Train Car Situation.* (15) Nov. 21.
Comparison of Freight Train and Canal Boat Resistance.* Harold A. Houston. (15) Nov. 21.
Heavy Maintenance Work on an Indian Railway.* (15) Nov. 21.
Chilled Iron Car Wheels for Electric Railway Service.* W. A. Bennett. (Paper read before the Central Elec. Ry. Assoc.) (17) Nov. 22.
Steel-Tired Forged and Rolled-Steel Wheels. M. D. Hayes. (Paper read before the Central Elec. Ry. Assoc.) (17) Nov. 22.
Electric Locomotives Replace Expensive Trucking Service.* (17) Nov. 22.
Ventilation of the Winston Tunnel, Chicago Great Western Ry.* (18) Nov. 22.
War Time Railroading in Mexico. Charles Hine. (Paper read before the St. Louis Ry. Club.) (18) Nov. 22.
The Continuous Rail in the United States.* (46) Nov. 22.
Soldier Summit Detour Line, Denver & Rio Grande R. R.* (18) Nov. 22.
Pacific Type Locomotives, Central of Georgia Ry.* (18) Nov. 22.
Methods of Supporting Railway Tracks During the Construction of Permanent Works.* (Abstract of Report of Committee of the Am. Ry. Bridge and Bldg. Assoc.) (86) Nov. 26; (87) Nov.; (18) Nov. 8.
Construction Methods at the Mont d'Or Tunnel with Particular Reference to the Difficulties Caused by Large Inbreaks of Water.* (86) Nov. 26.
A Proposed Municipal Hydro-Electric Railway for Toronto and North-Eastern District.* (96) Nov. 27.
The Transandean Railway from Arica, Chili, to La Paz, Bolivia.* G. H. Sawyer. (13) Nov. 27.
New Line over Wasatch Mountains, Utah.* (15) Nov. 28.
The Freight Rate Advance Hearings. (15) Nov. 28.
Plans for Federal Valuation of Common Carriers. (14) Nov. 29.
Arnold Report on Chicago Railroad Terminals. (14) Nov. 29; (18) Nov. 22.
Les Heurtoirs à Glissement et les Voies Ensablées: Essais des Chemins de Fer du Nord et de l'Etat.* Goupil. (43) Sept.
Le Chemin de Fer Electrique de Cerdagne de Villefranche-de-Conflent à Bourg-Madame.* Delmas. (43) Sept.
Note sur le Développement de la Traction Electrique en Italie.* Parodi. (38) Nov.
Transport et Manutention des Minerais de Fer, en Tunisie.* L. Félix. (38) Nov.
Les Locomotives Electriques à 15 000 Volts du Chemin de Fer des Alpes Bernoises (Berne-Loetschberg-Simplon).* Ch. Jaquin. (33) Nov. 1.
L'Accident de Chemin de Fer de Melun.* J. Trévières. (33) Nov. 15.
Verschiebung eines Weichen- und Signalstellwerkes im Betriebe.* Niemann. (48) Oct. 4.
Spezialtransportwagen für Schmalspur-Fahrzeuge.* (107) Oct. 25.
Heissdampf-Tenderlokomotiven Serie Ea 3/6 der Bern-Neuenburg-Bahn.* (107) Nov. 1.
Der theoretische Längenschnitt von Drahtseilbahnen mit Doppelbetrieb.* R. von Reckenschuss. (102) Serial beginning Nov. 1.
Die Mechanik der Zugbewegung bei Stadtbahnen.* (102) Nov. 1.
Anlagen zum Bekohlen und Besanden von Lokomotiven und zum Verladen von Schlacke und Asche auf den Bahnhöfen Oberhausen und Frintrop. O. de Haas. (102) Nov. 1.
Die Einphasen-Wechselstrom-Hauptbahn Spiez-Brig (Lötschbergbahn).* (41) Serial beginning Nov. 6.
Lokomotiv-Drehkran mit Akkumulatoren-Antrieb.* (107) Nov. 8.
Bericht und Kreditbegehren der Schweiz. Bundesbahnen zur Einführung der elektrischen Traktion auf der Gotthardbahn.* W. Kummer. (107) Nov. 15.
Quellen und Klüfte im Grenchenberg-Tunnel.* Max Custer. (107) Nov. 15.

Railroads, Street.

Single-Phase Traction.* Marius Latour. (77) Oct.
High-Tension Continuous-Current Traction. Louis Gratzmuller. (77) Oct.
Fender and Wheel-Guard Tests in Vancouver.* (17) Nov. 1
Cost of Subway Construction: Diagrams for Facilitating Preliminary Estimates of Cost.* Frank H. Carter. (86) Nov. 5.
Standardization of Street Railway Special Work.* A. E. Harvey. (From *Electric Traction.*) (96) Nov. 6.

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New Carhouse of the Muskogee Electric Traction Company.* (17) Nov. 8.
Truckless and Single-Truck Center-Entrance Cars.* (17) Nov. 8.
Pneumatic Caisson Piers for New York Subway Tunnel. (14) Nov. 8.
St. Louis Center-Entrance Motor Car.* (17) Nov. 15.
Subway Tunnel under Harlem River.* (14) Nov. 15.
Compensation for Street-Railway Use of Highway Bridge. (14) Nov. 15.
Present Status of the Subway Situation in Chicago. William J. Shanks. (13) Nov. 20; (18) Nov. 22.
Overcoming Difficulties in New York Subway.* (14) Nov. 22.
Cincinnati Traction Company's Track Construction Methods.* (17) Nov. 22.
Bus Operation in London and Paris. John A. McCollum. (Report to the Board of Estimate and Apportionment.) (17) Nov. 22.
Operating Data of a Large Railway Power Plant, Twin City Rapid Transit Co., Minn.* (27) Nov. 22.
The Illumination of Street Railway Cars. L. C. Porter and V. L. Staley. (Abstract of paper read before the Illuminating Eng. Soc.) (62) Nov. 24; (17) Nov. 22.
Central-Station Energy for Chicago Railways. (27) Nov. 29.
Latest Features of Montreal Cars.* (17) Nov. 29.
Paving Protector Used with T-Rail in Memphis, Tenn.* (17) Nov. 29.
Railways and Subways at Buenos Aires.* F. Lavis. (14) Nov. 29.
La Traversée de la Butte Montmartre par le Chemin de Fer Electrique Nord-Sud de Paris, Ligne Saint-Lazare-Portes de Saint-Ouen et de Clichy. Henri Brot. (33) Oct. 25.
Zeitintervalle beim Anlassen von Bahnmotoren.* Conrad Irányi. (41) Nov. 20.

Sanitation.

Miners' Nystagmus and Its Effect on Vision. J. Court. (Paper read before the Midland Inst. of Min., Civ. and Mech. Engrs.) (106) Vol. 46, Pt. 1.
Sewage Screenings. T. C. Schaetzle and E. R. Davis. (36) Nov.
Sewage Disposal Plant at Springfield, Mo.* (60) Nov.
Vacua Hot-Water Heating Applied to Woolworth Building.* Ira N. Evans. (64) Nov. 4.
Sacramento Valley Land Reclamation.* (86) Nov. 5.
Studies of River Bottoms at Philadelphia in Relation to Sewage Disposal.* (13) Nov. 6.
Eversham Sewage Works Extensions.* (104) Nov. 7.
Vapor-Heating in an Orphan Asylum.* (101) Nov. 7.
Recent British Views on Dilution Desirable for Sewage and Sewage Plant Effluents.* G. McGowan, Colin C. Frye, and G. B. Kershaw. (Report made to the Royal Comm. on Sewage Disposal.) (86) Nov. 12.
Progress of Construction and Works Planned for Early Construction on the Sag Branch of the Chicago Drainage Canal.* (86) Nov. 12.
Sanitary Surveys of Rivers. J. R. Malek. (Paper read before the Canadian Public Health Assoc.) (96) Nov. 13.
Sewage Pumping Machinery and Appliances.* Gerald Priestman. (96) Nov. 13.
Operating Costs in Heating Plants. H. M. Hart. (Paper read before the Am. Soc. of Heating and Ventilating Engrs.) (101) Nov. 14.
The Need for Standardisation in Drainage Details. Arthur Palmer. (Paper read before the Institution of Municipal Engrs.) (104) Nov. 14.
Care of Streets in Chicago. (14) Nov. 15.
Sewage Disposal, How to Build a Plant for the Country Home.* Benjamin Brooks. (76) Nov. 18.
Time Studies and Factors and Standards for Street Cleaning in Chicago. (86) Nov. 19.
Dual Water-Supplies and Typhoid Fever at Philadelphia. (13) Nov. 20.
Sewer Construction in Quicksand. (13) Nov. 20.
Plumbing and Heating Chicago Apartments.* (101) Nov. 21.
The Separation of Grease from Sewage Sludge, with Special Reference to Plants and Methods Employed at Bradford and Oldham, England.* Kenneth Allen. (86) Nov. 26.
Unsatisfactory Operation of Sewage and Trade Waste Treatment Plants at Monticello, N. Y.* (86) Nov. 26.
A Suggested System of Accounts, Records and Reports for Sewer Departments. (86) Nov. 26.
Recent Investigations of the Bactericidal, Deodorizing and Physiologic Action of Ozone. (13) Nov. 27.
Six Current Features of Public Water Supplies. (Report made to the Am. Public Health Assoc.) (13) Nov. 27.
Subaqueous Sewer Construction, Brooklyn, N. Y.* (13) Nov. 27.
Preparatory Treatment of Sewage, Observations and Experiments. Charles Gilman Hyde. (Paper read to the League of Pacific Northwest Municipalities.) (96) Nov. 27.

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Combination Heating in Maine Schoolhouse.* (101) Nov. 28.

Special Ward Heating and Ventilation.* H. S. Knowlton. (64) Dec. 2.

Geigersche Kanalartikel und Neuerungen an Armaturen für Haus-Entwässerung.* (7) Oct. 18.

Die neue Abwasserreinigungsanlage der Stadt Trier.* T. Schürmann. (7) Oct. 25.

Beitrag zum Berechnen der Warmwasserbereitung.* Rud. Korbmacher. (7) Oct. 25.

Die Heizungs- und Lüftungsanlage im Schweiz. Nationalbank-Gebäude in Bern.* L. Greiner. (107) Serial beginning Nov. 1.

Berechnung von Warmwasser-Heizanlagen.* G. de Grahl. (7) Nov. 1.

Expansions- und Sicherheits-Vorrichtungen gegen Ueberdruck und Ueberkochen von Warmwasserbehältern.* H. Roosa. (7) Nov. 1.

Structural.

A Method of Checking the Economical Height of an Office Building. C. T. Coley. (Paper read before the National Convention of Bldg. Owners and Mgrs.) (8) Oct.

The Decorative Possibilities of Concrete.* C. W. Boynton and J. H. Libberton. (4) Oct.

Constructing a Ten-Story Concrete Building.* (67) Nov.

Methods for Testing Concrete Waterproofing. Cloyd M. Chapman. (Paper read before the National Assoc. of Cement Users.) (67) Nov.

Cracks in Concrete.* (Abstract of Report to the British Concrete Inst.) (67) Nov.

The Problems of the Contractor.* Leonard C. Wason. (Paper read before the Boston Soc. of Civ. Engrs.) (1) Nov.

The Connell Colliery Hospital.* (45) Nov.

Transverse Strength of Screws in Wood.* Andrew Kolberk and Milton Birnbaum. (36) Nov.

Preservation of Timber. (Report of Committee of the Am. Ry. Bridge and Bldg. Assoc.) (87) Nov.

The New City Hall of San Francisco.* (60) Nov.

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*Illustrated.

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Vol. XXXIX. DECEMBER, 1913. No. 10.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

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REINFORCED CONCRETE RESERVOIR AND COAGULATION PLANT AT ST. LOUIS, MO.

By Edward Flad, M. Am. Soc. C. E.

To be Presented February 4th, 1914.

Before describing the design and construction of the reservoir and coagulation plant which are the subjects of this paper, a short explanation of the water-works system to which they belong may not be amiss.

The City of St. Louis has guarded zealously the right to supply water to its citizens, but it has no power to prevent the owners of riparian rights from taking water from the river and leading it to industries on the river front, if no streets, alleys, or public places are crossed or entered on by the pipe lines. Thus, there has developed, in connection with the Anheuser-Busch Brewery, in that city, a water-works system with a capacity of more than 6 000 000 gal. per day, or sufficient to supply the needs of a city having a population of 80 000 people.

The city is perhaps justly proud of the improvement made a few years ago in the quality of its water supply, which improvement was accomplished by the simple process of dumping into the water suitable chemicals which hasten sedimentation. This just pride should be

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

tempered, however, by the knowledge that, as early as 1901, several years before the city fathers could be prevailed on to adopt modern methods, the Anheuser-Busch Brewery had pointed out the way, by taking its water supply from the Mississippi River and clarifying it by the use of a chemical coagulant and rapid filtration—a further refinement of the method adopted later by the city.

The water-works of the Anheuser-Busch Brewery are on the river front, south of Dorcas Street. The water is taken from the Mississippi through two 20-in. cast-iron intake pipes, and is siphoned into one of two intake wells, from which it is pumped into settling tanks. It flows by gravity through the settling tanks, thence through the filters, and is then pumped into the distribution system.

The low-service pumps are in a brick pit, 30 ft. in diameter and 40 ft. deep. There are three centrifugal pumps having a combined capacity of 13 000 000 gal. per day, and one triplex, direct-acting pump having a capacity of 2 000 000 gal. per day.

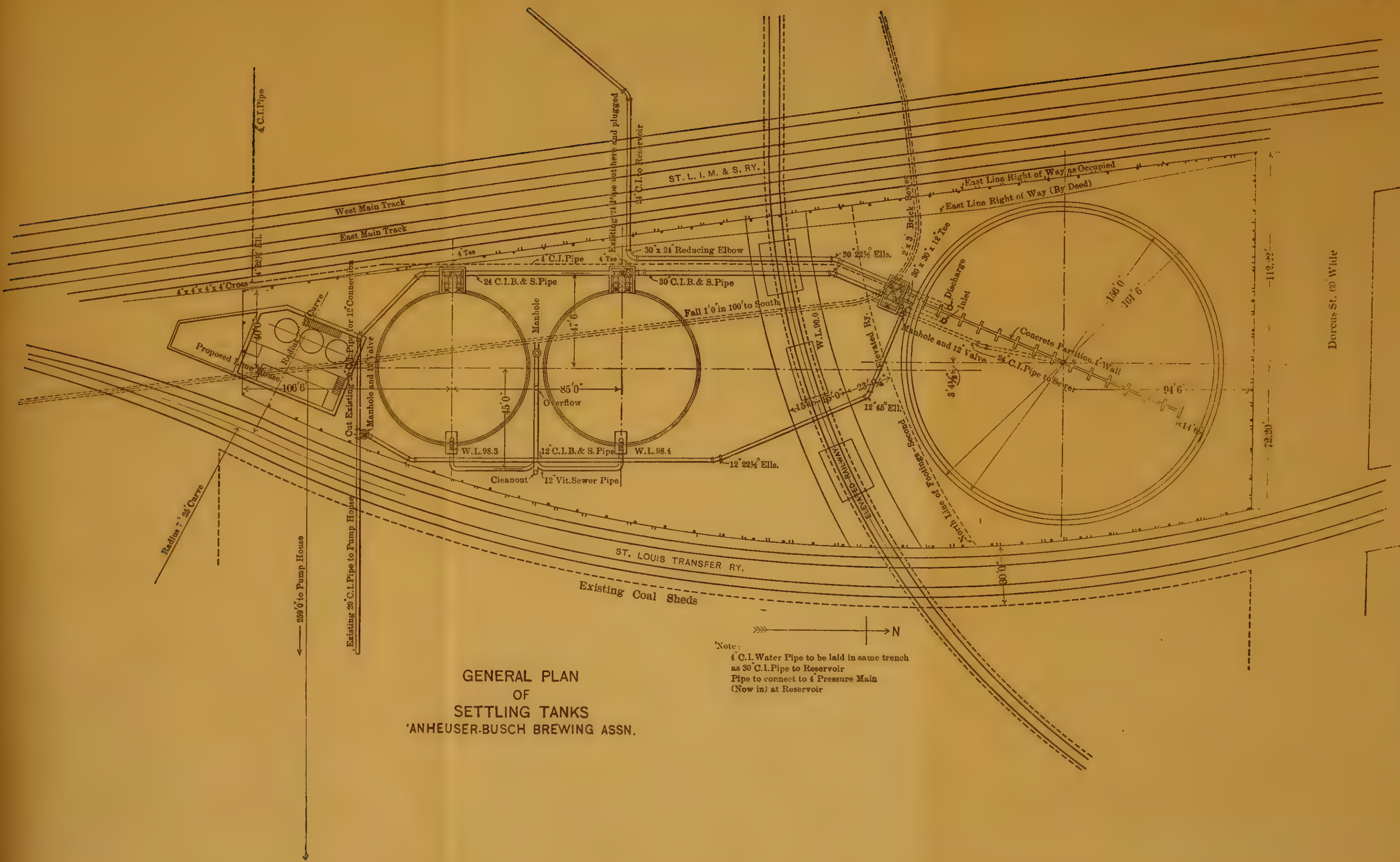
There are two steel settling tanks, 75 ft. in diameter and 28 ft. high, one circular concrete reservoir approximately 150 ft. in diameter and 30 ft. deep, and one rectangular covered reservoir having a capacity of about 1 000 000 gal.

The filter plant comprises six Jewell filters, circular in plan, each 16 ft. in diameter, and three Reisert filters, recently completed, which are rectangular in plan, each being approximately 34 by 15 ft.

Chemical Treatment.—The water is settled by adding sulphate of aluminum (alum) and lime. A special three-story reinforced concrete building is provided for storing and preparing the chemicals.

The hopper for storing the lime is 36 by 9 by 14 ft. high, and has a capacity of 90 tons. It is placed in a pit so that it can be filled directly by shoveling from the cars. An electric elevator conveys to the third floor the hand-cars containing the lime or alum.

The alum is dissolved in a concrete tank, and is fed to the water by gravity. This alum tank has three rectangular divisions, each 10 by 7 by 5 ft. deep. Each division is charged with from 500 to 2 000 lb. of alum which is dissolved in water. It requires from 2 to 5 hours to dissolve one charge. The lime is slacked in iron tanks on the third floor. These tanks are rectangular, 12 by 12 by 7 ft. deep, with sloping bottoms. A false perforated bottom is provided at a depth of 30 in., on which the lime is placed and partly submerged in 1 ft. of water.



Note:
4" C.I. Water Pipe to be laid in same trench as 30" C.I. Pipe to Reservoir
Pipe to connect to 4" Pressure Main (Now in) at Reservoir

GENERAL PLAN
OF
SETTLING TANKS
ANHEUSER-BUSCH BREWING ASSN.

After slaking, which requires about 1 hour, the attendant stirs the mixture, which passes readily through the perforated bottom and into the lime tanks below. This milk of lime is stored in three vertical cylindrical iron tanks, 12 ft. in diameter and 18 ft. high, with conical bottoms. One charge of lime consists of from 2 000 to 6 000 lb., and the tank holds about 10 000 gal. of water, giving a 2½ to 7% solution. In these tanks the milk of lime is kept agitated by compressed air admitted at the bottom through a small perforated pipe.

The flow of both the alum and lime solutions is regulated by standardized orfices operating under fixed heads. The milk of lime is pumped into the supply pipe or settling tanks by a centrifugal pump. As a general rule, the lime is added to the water as it enters the first settling tank, and the alum as the water enters the second settling tank.

Consumption.—The maximum consumption of water during the summer is about 6 000 000 gal. per day, for which at times, 1 600 lb. of alum and 5 600 lb. of lime are required, or about 2 grains of alum and 7 grains of lime per gallon of water.

The water is used for boiler purposes, for condensing and cooling in connection with the ice machine, as well as for washing barrels, bottles, etc. It is not used in brewing beer, partly because of the natural prejudice against water taken from the river below the outlet of the large city sewers.

Reinforced Concrete Reservoir.—Reverting now to the reinforced concrete reservoir recently completed: After due consideration of the various possibilities as to the shape and location of the reservoir, a circular shape was decided on, and the diameter was made as large as the available space permitted. The elevation of the top was fixed by that of the water in the old settling tanks, which operate in series with the new reservoir; and the bottom was placed sufficiently low to pass below the fill of cinders and rubbish, and rest on the river silt.

Estimates were made of the comparative cost of a steel tank and a reinforced concrete reservoir. Exclusive of the foundations, pipes, gate-house, and accessories common to both designs, the steel tank was estimated to cost \$32 000, and the reinforced concrete reservoir, \$30 800. The reinforced concrete reservoir was supposed to have some advantage, being a more permanent form of construction and not requiring painting, and perhaps a desire to follow the latest fashion

had a minor influence; at all events it was decided to use reinforced concrete.

The reservoir has vertical sides and is 153 ft. 6 in. in diameter at the top and 35 ft. deep at the center. The side-wall extends 25 ft. 6 in. above the ground. The capacity is approximately 4 250 000 gal. There is a central partition, consisting of a 4-in. reinforced concrete wall with buttresses, which starts at one side of the reservoir and passes diametrically across to within 14 ft. of the other side. The object of this partition is to make the entering water circulate around the reservoir before reaching the outlet. The diameter of the intake and outlet pipes is 30 in., and that of the waste pipe 24 in. The outlet pipe has a float and a hinged joint, so that water is always taken from near the surface. The valves controlling the flow are in a gate-chamber outside the reservoir.

Foundation.—The foundation is a 12-in. layer of concrete resting directly on the river silt and reinforced, in two directions at right angles, with 1 in. square bars, 2 ft. from center to center, making $\frac{1}{2}\%$ reinforcement each way.

On top of this foundation rests the bottom of the reservoir, which is 6 in. thick and reinforced in a manner similar to the foundation, except that the bars are $\frac{1}{2}$ in. square and 6 in. from center to center.

The top of the foundation was coated with a thin layer of coal-tar, the object being to provide for expansion and contraction of the bottom independent of the foundation.

Side-Walls.—The thickness of the concrete side-walls is 7 ft. 6 in. at the base, 2 ft. 5 in. at the ground line, and 12 in. at the top. The pressure of the water is carried by hoop tension, the side-walls being reinforced circumferentially with corrugated round bars, under the assumption that the concrete carries no tension. There are three lines of $1\frac{1}{4}$-in. round bars at the bottom and two lines of $\frac{3}{4}$-in. round bars at the top, the sections and spacing being varied from bottom to top to correspond with the pressure. It was intended to allow a stress of 15 000 lb. per sq. in. on the bars. Owing to an error in the calculation, which, happily, was on the safe side, an excess of steel was used, making the stress per square inch somewhat less than that originally contemplated.

The thickness of the concrete wall was fixed at each point so that the concrete would not be stressed more than 290 lb. per sq. in., under

FIG. 1.—WOODEN FORMS FOR SIDE-WALLS OF RESERVOIR. STAR-SHAPED BOTTOM, AND VALVES ON INLET AND OUTLET PIPES.

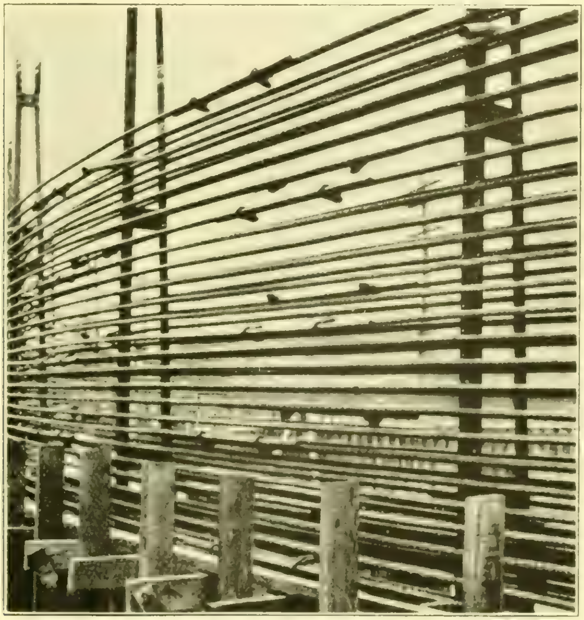
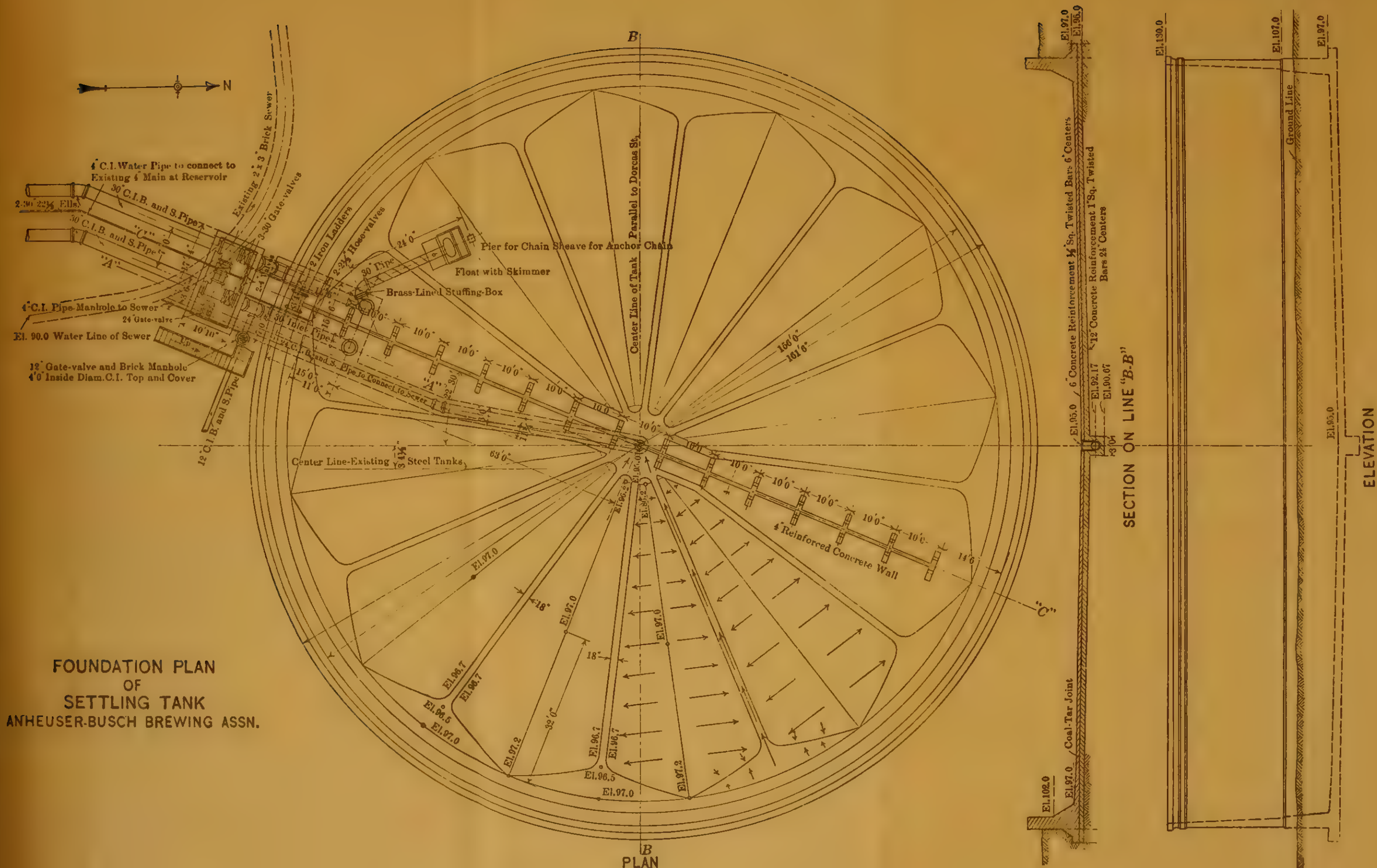


FIG. 2.—BARS FOR SIDE-WALLS OF RESERVOIR, WITH ANGLE-IRON SUPPORTS FOR BARS, ETC.


FOUNDATION PLAN
OF
SETTLING TANK
ANHEUSER-BUSCH BREWING ASSN.
PLAN
SECTION ON LINE "B-B"
ELEVATION
Pier for Chain Sheave for Anchor Chain
Float with Skimmer
Brass-Lined Stuffing-Box
Center Line of Tank Parallel to Dorcas St.
Center Line-Existing Steel Tanks
4" Reinforced Concrete Wall
Existing 2' x 3' Brick Sewer
3-30" Gate-valves
2 Iron Ladders
El. 90.0 Water Line of Sewer
12" Gate-valve and Brick Manhole
4' 0" Inside Diam. C.I. Top and Cover
6" Concrete Reinforcement ½" Sq. Twisted Bars 6" Centers
12" Concrete Reinforcement 1" Sq. Twisted Bars 24" Centers
Coal-Tar Joint
Ground Line

Arrangements for Washing Out.—The bottom of the tank slopes toward the center from all sides, the 24-in. waste outlet being at the center. The slope toward the center could not readily be made more than 2 in 75, being limited by the depth of the sewer which was already built. In order to facilitate the removal of sediment, therefore, the bottom was laid out in a series of star-shaped mounds, as indicated on Plate C, each mound draining into a shallow gutter. Hose connections furnish water under pressure for cleaning out.

Bond in Concrete.—Special precaution was taken to obtain a good bond between the successive layers of concrete. The old surfaces were scrubbed with brushes and a stream of water. In addition, 6-in. strips of corrugated plates, about $\frac{1}{16}$ in. thick, were placed vertically in the joints. In spite of these precautions, when the reservoir was filled, small leaks developed along most of the joints, and efflorescence was quite extensive. These leaks appear to be closing up gradually, and it is probable that in the course of time they will disappear entirely. The intention, however, is to empty the reservoir and treat the joints with some water-proofing compound.

After completion the outside of the wall was rubbed with carborundum blocks and brushed with cement mortar.

The reservoir was designed by the writer's company, and was built under contract by the Fruin-Colnon Contracting Company. The cost, including pipes and accessories, was approximately \$52 000. The unit prices and total cost of the various classes of work were as follows:

Excavation, 7 801 cu. yd. at \$0.80....................	\$6 240.80
Plain concrete, Class A, 58.2 cu. yd. at \$4.00.........	232.80
" " " B, 281.3 " " " 5.00.........	1 406.50
Reinforced concrete, 12-in. base, 759 cu. yd. at \$5.00...	3 795.00
Reinforced concrete, 6-in. bottom, 473.1 cu. yd. at \$8.00	3 784.80
Reinforced concrete side-walls, 1 178.3 cu. yd. at \$11.00.	12 961.30
Reinforced concrete partition, 120 cu. yd. at \$20.00....	2 400.00
Reinforcing bars, 582 668 lb. at 1¾ cents..............	10 196.69
Clips for reinforcing bars..........................	650.00
Ladders and angle-iron supports.....................	852.16
Cast-iron pipes and valves..........................	7 283.00
Gate-house..	1 200.00
Miscellaneous.......................................	844.59
Total cost..................................	\$51 847.64

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A STUDY OF FLUID RESISTANCE.*

By Luther Wagoner, M. Am. Soc. C. E.

The study of hydrodynamics by the usual method of differential equations, despite the fact that the brightest mathematical minds have attempted the subject, has thus far brought forth no results of a practical nature applicable to such fluid resistances as the steady flow in pipes, or for the resistance of a fluid at rest to the steady motion of a solid in the fluid.

The subject is full of difficulties and nearly impossible of any direct treatment by known mathematical methods.

For a long time the writer has held the belief that there is such a similarity in the nature of the resistances of a solid moving in a fluid, or of a fluid moving in a pipe or channel, that it might be profitable to make comparison of the motions of each, using such experimental data as are available, and that such a joint study might also prove useful in that any information thus gained about one would be helpful to resolve any doubts about the other. The general method used is that of a logarithmic diagram of experimental results obtained, combined with simple mathematics sufficient to explain the locus of the lines thus found. The results obtained represent a considerable advance in information about both subjects. Summarizing what fol-

*This paper will not be presented at any meeting, but written communications on the subject are invited for subsequent publication in *Proceedings*, and with the paper in *Transactions*.

lows, it is shown that, for bodies moving in a fluid at rest, or for a fluid moving along a surface at rest, there is for both the same general law of resistance; and, also, as a result of such studies, there is presented to the hydraulic engineer the first rational theory of the laws governing the flow in pipes.

There being but scanty information about the motion of bodies in a fluid, this study was made first, and from the results found the way was made easier for the study of fluid motion in pipes, and they are here given in the order named.

Part I.—The Terminal Velocities of Bodies in a Fluid Medium.

A body falling, or rising, in a fluid medium does so with accelerated velocity and increased resistance; when the resistance becomes as great as the impelling force, there is uniform motion, more commonly called the terminal velocity. (In a frictionless liquid, this would not occur, but in an actual liquid it does occur, and uniform motion is attained very rapidly.)

The Experimental Data.—For the purposes of this paper, the writer has selected data from the following sources:

"Velocity of Galena and Quartz Falling in Water," by Professor Robert H. Richards.* These are grains of mineral from 11.93 to 0.00152 mm. in diameter, but have a special value due to the long range covered.

Mr. H. S. Allen.† Steel balls in water, amber spheres in water, paraffin wax spheres rising in aniline, air bubbles rising in water and aniline.

"On the Viscosity of Liquids," by Mr. O. S. Jones.‡ The determination of the viscosity of glycerine by dropping small spheres of mercury and noting the diameter and velocity.

"On the Maximum Velocity Acquired by Small Bodies Falling in Water and Glycerine," by the writer.§

Also, for confirmatory use, "The Terminal Velocity of Small Spheres in Air," by John Zeleny and L. W. McKeehan.‖

* *Transactions*, Am. Inst. of Min. Engrs., 1907, pp. 210-235.

† *Philosophical Magazine*, Vol. 50, 1900.

‡ *Philosophical Magazine*, 1894.

§ *Transactions*, Technical Soc. of the Pacific Coast, Vol. V, p. 32, 1888.

‖ *Physical Review*, Vol. CLXIX, p. 535, May, 1910.

Notation.—The centimeter-gram-second system of units is used.

D = Diameter of the grain or sphere;

s = Specific gravity of the solid;

Δ = Difference of specific gravity of the solid and the fluid medium;

V = Terminal velocity of the body;

D_c = Critical diameter;

V_c = Critical velocity;

μ = Coefficient of viscosity = in water to

$$\frac{0.017944}{(1 + 0.023121\ T)}\ 1.5423;$$

ν = Kinematic coefficient of viscosity = $\frac{\mu}{\rho}$;

ρ = Density of the fluid medium;

K_0, K_1, K_{11}, K_2 = Coefficients;

$a, b, c,$ = Constants or general coefficients;

θ = Coefficient of form, or shape of body;

ϕ = Coefficient of roughness, or surface condition;

n = Exponent;

log. = Common logarithm;

tan. = Tangent;

tan. h. = Hyperbolic tangent.

TABLE 1.—PHYSICAL CONSTANTS OF THE DATA.

Material.	Form.	Specific Gravity.	Medium.	Density.	Δ.	μ	Experimenter. Remarks.
		S		ρ			
Galena........	Grains...	7.50	Water	1.00	.....	0.01 ±	Richards.
Quartz	Grains...	2.65	Water	1.00	....	0.01 ±	"
Steel	Balls.....	7.731	Water	1.00	6.731	0.0125	Allen.
Amber	Spheres..	1.07683	Water	1.00	0.07683	0.011	"
Paraffin	Spheres..	0.907	Aniline	1.038	0.131	0.06023	"
Mercury......	Spheres..	13.59	Glycerine..	1.260	12.33	10.69	Jones.
Glass.........	Spheres .	2.61	Glycerine..	1.24	1.37	3.428	Wagoner. Viscosity computed.
Air	Bubbles .	0.0012	Water......	0.9988	1.00	0.01404	Allen
Air	Bubbles .	0.0012	Aniline ...	1.0368	1.038	0.06023	Allen.
Lycopodium..	Spheres..	1.175	Air	.....	......	0.000185	$D = 0.00316$ $V = 1.76$
Polytrichium	Spheres..	1.53	Air	.....	......	0.000185	$D = 0.000956$ $V = 0.228$
Lycoperdon..	Spheres..	1.44	Air	....		0.000184	$D = 0.000418$ $V = 0.0467$

Graphical Representation of the Experimental Data. For the purpose of discovering laws, the method of platting logarithms of velocities divided by logarithms of diameters was first used. This was not

entirely satisfactory, especially for the grains. The unavoidable uncertainties about the diameter and velocity give (as can be seen by reference to the original paper) a certain impression of indefiniteness as to what actually happened; or, if any sharply-defined critical points exist, this, coupled with the smooth free-hand curve drawn through the points, misled the writer for some time as to the true nature of the data. Although it is a subject for regret that information was not given as to weights of grains, surface, and viscosity, the original paper, because of its long range, is still very valuable, and without its aid the writer would not have attempted this paper.

In casting about for new devices for logarithm platting, an original method, and believed to be new, has been used.

Theorem.—If $V = f\,D^n$ and both V and D are affected by probable errors of $\pm\, p$ and $\pm\, q$, respectively, then $V\,D^{\pm 1} = f\,D^{n \pm 1}$ is the most probable value of the new function.

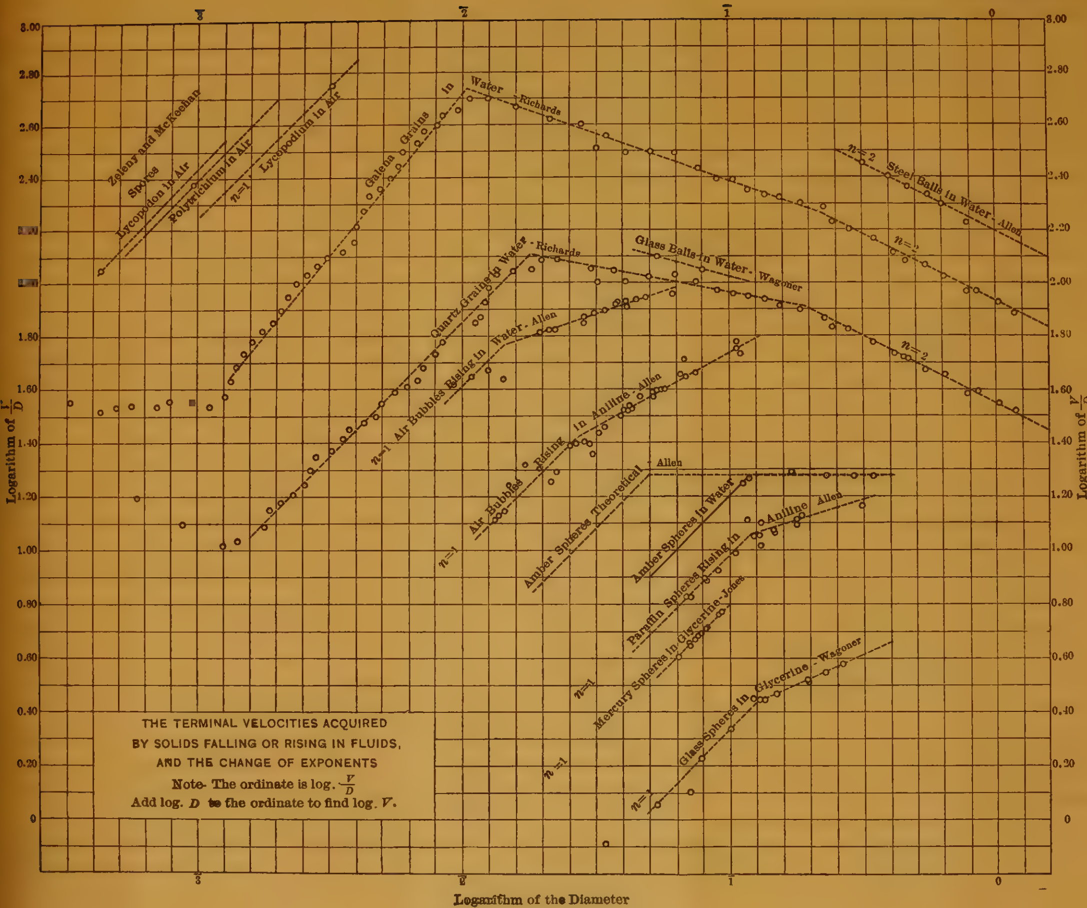
Proof.—This is proved by the direct multiplication of $V \pm p$ by $D \pm q$, when both p and q disappear, or graphically by platting four possible points of $\frac{V}{D}$ and taking the center of gravity of the figure as the most probable point.

Making $\frac{\log.\ V\ D}{\log.\ D}$ gives a longer and smoother curve, but the angles of intersection of the different branches of the curves are not as well defined as by using $\log.\ \frac{V}{D}$ as ordinate and $\log.\ D$ as abscissa, and this method has been used and is shown on Plate CII, where it is seen that, for the grains, a very satisfactory definition of the intersections of the three branches has been obtained; also—which is new—it is seen that, for the first time, there is shown to exist for all bodies and fluids three stages of flow, their exponents being 1, n, and 2; and each is accompanied by a rather sudden transition from one stage to another (which might be compared to the action of a balance; when equilibrium is reached there is unsteady motion and when passed the beam drops).

Explanation of Plate CII.—It is observed that for the first stage the slope of the lines for $n = 1$ is tan. $= 1$, and for $n = 2$, the slope is tan. $= -\frac{1}{2}$; from which there is found

$$n = \frac{3}{\text{tan.} + 2} \qquad (1)$$

PLATE CII.
PAPERS, AM. SOC. C. E.
DECEMBER, 1918.
WAGONER ON
FLUID RESISTANCES.



THE TERMINAL VELOCITIES ACQUIRED
BY SOLIDS FALLING OR RISING IN FLUIDS,
AND THE CHANGE OF EXPONENTS

Note- The ordinate is log. $\frac{V}{D}$
Add log. D to the ordinate to find log. V.

If $\dfrac{\log. V}{\log. D}$ had been platted, then the relation would have been

$$n = \frac{3}{\tan. + 1} \qquad \text{(2)}$$

and

$$\tan. = \frac{3}{n} - 1 \qquad \text{(3)}$$

Plate CII has been used for the purpose of finding n and the tangent, and the coefficients, K_1, K_n, K_2, etc.; the results are tabulated as if the diagram was in accordance with Equations (2) and (3), or $\dfrac{\log. V}{\log. D}$.

The effect of using $\log. \dfrac{V}{D}$ as ordinate, is to increase greatly the angle of intersection of the first and second branches of the curves. Thus, for galena, where $n = 1.82$, and using each form of ordinate, there is for each branch the following angles:

	$n = 1$	$n = 1.82$	$n = 2$	
Ordinate $= V$	$+ 63° 26'$	$+ 33° 45'$	$+ 26° 34'$	differences $= 17° 41'$, $7° 11'$
Ordinate $= \dfrac{V}{D}$	$45°$	$- 18° 20'$	$- 26° 34'$	" $= 63° 20'$, $8° 14'$

This great increase of intersection angle, where n is greater than 1.50, makes the locus of the lower critical point more easily found from the data; making the ordinate $= VD$, gives a longer and smoother curve with greatly reduced angles of intersection, and in certain cases all three methods might be found helpful if there is much irregularity of data.

Table 2 shows the data contained on Plate CII.

TABLE 2.—DATA TAKEN FROM PLATE CII.

Material.	Medium.	$\log. D_c$	$\log. V_c$	$\log. K_1$	$\log. K_n$	$\log. K_2$	tan.†	Exponent n.
Steel balls	Water	....	....	....	....	2.2043	....	2.00
Galena grains	Water	8.02*	0.74	4.700	2.013	1.935	0.6487	1.82
Quartz grains	Water	8.262	0.37	3.846	1.723	1.546	0.7928	1.673
Air bubbles	Water	8.1837	9.9659	3.5985	2.3880	....	1.3335	1.2857
Air bubbles	Aniline	8.426	9.848	2.996	....	....	1.558	1.173
Amber spheres	Water	9.086	0.363±	2.1907	1.2646	....	0.9865	1.510
Paraffin spheres	Aniline	8.993	9.9647	1.9787	1.3566	....	1.3823	1.2592
Mercury spheres	Glycerine	....	....	1.7984	....	....	....	....
Glass spheres	Glycerine	9.1166	9.5602	1.3270	....	....	1.444	1.2275
Glass spheres	Water	8.3226	0.5263	3.8823	1.7665	....	0.739	1.7250
Lycopodium spheres	Air	....	....	5.246	....	....	....	1.0
Polytrichium spheres	Air	....	....	5.359	....	....	....	1.0
Lycoperdon spheres	Air	....	....	5.427	....	....	....	1.0

* = 8.02 — 10.

† The tan. is scaled from the plat, and 1 has been added to it to make it of the form. $\log. V =$ ordinate.

From the data in Table 2, in which there are many gaps, it will be attempted to find the missing parts, and the result of the investigation appears as dotted or full lines on Plate CII.

On the Present State of Knowledge Concerning the Terminal Velocity of Bodies, Falling or Rising, in Fluids.—An immense amount of purely analytical work has been done by various eminent mathematicians and physicists in an effort to solve the problem, both for viscous and non-viscous fluids, but with few notable results of an applicable nature, probably for the reason that the theoretical work did not follow and interpret experiments, rather than precede them.

Sir Gabriel Stokes, many years ago, gave a solution for very small bodies falling in a viscous medium. The solution is correct, but is limited in its application by a condition, namely, radius^2 $\times$ velocity $\div$ viscosity, must be small; that is to say, the higher powers of $\frac{r^2 v}{\mu}$ can be ignored. In fact, Stokes says that the solution was obtained by neglecting the higher-power terms of the general equation. Concerning the higher velocities, it has long been known that the resistance varies as V^2 and is independent of the viscosity. For still higher velocities, such as for cannon balls, the resistance varies as a power intermediate between the second and third. About the powers intermediate between 1 and 2, nothing is known, nor is the state recognized by any previous writers. It thus appears that if the diameter be uniformly increasing, the order of exponents will be:

D_1 to D_2—Resistance varies as V^1
D_2 to D_3 " " " V^n
D_3 to D_4 " " " V^2
D_4 to D_5 " " " V^{2+c}

and the transition from an exponent to the next higher will be somewhat abrupt. (This is subject to later remarks about a possible change of exponent for D_0 to D_1 where $R \sim V^{1-}$).

Working Hypothesis.—Mr. H. S. Allen, whose observations are used in this paper, proposed a general formula to cover all values of the exponent. He assumes a resistance

$$R = k \text{ Velocity}^x \text{ Radius}^y \text{ Viscosity}^w \text{ Density}^z;$$

and, using dimensional methods, the above becomes

$$\text{Force} = \text{Resistance}.$$

$$M\,L\,T^{-2} = k\left\{(L^x\,T^{-x})\,(L^y)\,(M^w\,L^{-w}\,T^{-w})\,(M^z\,L^{-3z})\right\} \quad .(4)$$

From M there is $1 = w + z$;

" L " " $1 = x + y - w - 3z$;

" T^{-2} " " $2 = x + w$

This can be solved by assuming $x = y = n$, when the resistance becomes

$$\text{Resistance} = k\,(V\,D)^n\,\mu^{2-n}\,\rho^{n-1} \quad \ldots\ldots\ldots\ldots\ldots (5)$$

For spheres, using diameter instead of radius, the completed equation is:

$$D^3\,\frac{\pi}{6}\,\Delta = k\,(V\,D)^n\,\mu^{2-n}\,\rho^{n-1} \quad \ldots\ldots\ldots\ldots\ldots (6)$$

Equation (6) is perfectly general and is correct, provided the fundamental assumption is correct. In its present form, it must be considered as quite elemental, as the coefficient, k, is not provided for; as will be shown later, it is a complex quantity, and additional terms, of the form, ϕ^{n-1}, and z^{n-1}, are required to express the resistance completely.

Apparently, Mr. Allen contented himself with proposing the formula, but does not appear to have developed it further, or put it to any experimental test. There appears to be a considerable degree of probability that Equation (6) can be made to represent experimental data accurately, and it will be used as the basis of what follows.

Application of Equation (6), for $n = 1$.—Making $n = 1$, Equation 6 reduces to (for spherical bodies)

$$D^3\,\frac{\pi}{6}\,\Delta = \frac{C\,V\,D\,\pi\,\mu}{g} \quad \ldots\ldots\ldots\ldots\ldots (7)$$

where C is a constant, probably related to the form of the body. π is introduced on the resistance side as a surface factor of D, and g is the constant of gravity. For cases where $\frac{D^2\,V}{\mu}$ is small, then C is exactly 3; hence, for normal spheres,

$$g\,D^2\,\Delta = 18\,V\,\mu \quad \ldots\ldots\ldots\ldots\ldots (8)$$

and lastly, making $D = 1$, there is

$$V = k_1\,\frac{g\,\Delta}{18\,\mu} \quad \ldots\ldots\ldots\ldots\ldots (9)$$

where $$K_1\,D^2 = V \quad \ldots\ldots\ldots\ldots\ldots (10)$$

Equation (8) gives the locus of the lines quite accurately for air bubbles, mercury, and glass bodies. For the light bodies (amber, $\Delta = 0.07683$, and paraffin, $\Delta = 0.131$) the foregoing value of 18 of Equation

(8) no longer holds true, and a correction for inertia is required. As a practical method, it is suggested to add to 18, $\frac{144}{g\,\Delta}$ for falling bodies and $\frac{72}{g\,\Delta^2}$ for rising bodies.

Using Equation (7), these corrections would be added to 3 π. For the case of irregular bodies, and generally hereafter, the quantity, 3 π, or its equivalent, will be called θ, such that, calling w a factor for the effective weight-producing motion, there is

$$D^3\,w = \frac{\theta\,D\,V\,\mu}{g} \quad \text{.....................} (11)$$

General Consideration of Equation (6).—Equations (7) to (11) show that the coefficient, k, of Equation (6) vanishes for $n = 1$, also that the quantity, θ, may be considered a factor related to the form of the body and also of its inertia terms. (It is probably the velocity function of hydrodynamical writers.) As it enters as a constant for any value of μ, it may be considered as joined to $V\,D$, or the resistance is of the form

$$\frac{1}{n}\left(\frac{V\,D\,\theta}{g}\right)^n$$

If a friction coefficient is assumed to exist, and it seems probable that the roughness of the surface must affect the motion in the stages where n is greater than 1, then it must be of the form, $\phi^{(n-1)}$. Also, a stream function can be considered a factor with similar exponent. Calling z the product of a fluid density, friction coefficient, and a stream function, then the final expression becomes

$$k\,(n - 1)\,z^{n-1}$$

the term, $n - 1$, being required to cause the whole expression to vanish, or become 1, when $n = 1$ Equation (6) then becomes, equating weight to resistance:

$$\text{Effective weight} = \frac{1}{n}\left(\frac{V\,D\,\theta}{g}\right)^n \mu^{2-n}\,k\,(n - 1)\,z^{n-1} \quad \text{.....} (12)$$

Equation (12) can also be written

$$\text{Effective weight} = \frac{\mu^2}{n\,z}\left(\frac{V\,D\,\theta\,z}{g\,\mu}\right)^n k\,(n - 1) \quad \text{............} (13)$$

in which form it is seen that the terms, $\mu^{(2-n)}$ and $z^{(n-1)}$ of Equation (12) do not require integration coefficients other than the $\frac{(n - 1)}{n}$ common to both equations.

Equating resistances of Equations (11) and (12), for the common V_c point, and reducing, there is

$$\mu = \left(k\frac{n-1}{n}\right)^{\frac{1}{n-1}} \frac{V_1 D_1 \theta z}{g} \quad \ldots\ldots\ldots\ldots\ldots(13)$$

making $n = 2$ and equating resistances for the common point or upper V_c, and reducing, there is

$$2\left(\frac{n-1}{n}\right)^{\frac{1}{2-n}} \mu = \frac{V_2 D_2 \theta z}{g} \ldots\ldots\ldots\ldots\ldots(14)$$

making V_1 D_1 of Equation (13) $= k_1 D^3 = \dfrac{g \Delta}{\theta \mu} D^3$, Equation (13) becomes

$$\frac{\mu^2}{\Delta z \left(k\frac{n-1}{n}\right)^{\frac{1}{n-1}}} = D_c^3 \ldots\ldots\ldots\ldots\ldots(15)$$

Special Value of $n = 2$.—Making $n = 2$, Equation (12) reduces to

$$2g \text{ weight} = kz\ (V D \theta)^2 \ldots\ldots\ldots\ldots\ldots\ldots(16)$$

which shows that in this stage the motion is independent of the viscosity, the latter having become μ^{2-2}, or 1. For exponents greater than 2, it is seen that μ enters the resistance with a minus exponent, thus increasing the resistance.

Approximate Values of n and D_c.—In a general way, the close of the $n = 1$ stage, or V_1 D_1 tends to a constant value, or

$$\log.\ V_1 D_1 = 2.68 \pm = 0.048.$$

$$\log.\ K_1 D^3 = 2.68 \pm = 0.048.$$

This seems to be true for the regular bodies, and subject to the conditions that $\dfrac{V D^2}{\mu}$ is small.

Calling $\left(\dfrac{3}{n} - 1\right)$ a tangent, or the actual slope line on a logarithmic diagram of the nth stage, then the following relation is quite close:

$$\tan. = e\ D_c^{\frac{1}{3}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(17)$$

where e is the Napierian base and D_c is a critical diameter, and from this is found

$$n = \frac{3}{e}(\log.\ k_1)^{\frac{1}{3}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(18)$$

Equations (17) and (18) are to be considered as approximations, subject to the above named limitation, that for regular bodies $\dfrac{V D^2}{\mu}$ must be small. Thus understood, they are useful for planning experiments or checking doubtful results.

Extremely Low Values of D and V_1.—Examining Plate CII, it is seen that at log. D = galena 3.04, quartz 3.14, an abrupt change occurs, the exponent increasing to 1.50, 1.60 ±. Professor Richards attributed this to convection currents. To the writer this appears to be a change in boundary conditions such that there can be and is an actual change of exponent.

Physical Concept.—Assuming that there is such a change of the law of exponents as just suggested, the whole subject might be viewed as follows:

When V is very small, suppose that a certain quantity of fluid be attracted to the body, such that its radius, R, becomes $R + r$, the line of slip then being over the greater boundary, this would also change the Δ, or density relation, so that for a given weight there would be a greater resistance, and hence an increased exponent. The compound grain or sphere could also be imagined to deform under increasing velocity, passing from spherical through elliptical forms and lastly reaching the condition of a quiet wake, when the $n = 1$ stage begins. At the close of the $n = 1$ stage the wake becomes turbulent, and at the end of the nth stage a new boundary condition begins; also, at the end of $n = 2$ another change in the boundary condition must occur.

Descending the scale of diameters, it seems probable that another law relating to the colloidal state of matter must enter about here as a factor, and the diameters where this change occurs (0.01 to 0.015 mm.) are about those required for the grains of Portland cement to become active (colloidal). Lastly, it is known of most colloids that when the diameter is sufficiently small there is permanent suspension. It would be interesting to test out Portland cement in this way, using a suitable fluid, and see whether a curve such as above noted would be coincident with the limit of size of the active grains as distinguished from the larger but inert grains.

If this view of an increased exponent should prove to be correct, then the order of succession of exponents is

$$\text{Exponents} = (1 + a),\ (1),\ (1 + b),\ (2),\ (2 + c),$$

which conveys the idea of periodicity of the exponent, or, if not periodic, it suggests the idea that the above changes of exponent are

subject to some law, at present unknown, which offers to become a profitable field for research work.

Conclusion.—It has been shown that bodies falling or rising in a fluid, on reaching their terminal velocities, follow a definite law of exponents as long as the boundary condition is unchanged. At or about such change there is a condition of unstable equilibrium, such that a slight increase in the diameter and velocity is accompanied by a sudden change in the law of resistance. For the further study of the question there are two methods: (*a*), by the general methods of differential equations, to attempt to deduce what law of resistance will be encountered; and (*b*), to make an explanation of the results found by proper mathematical reasoning. The first method gives no check on the result obtained, and the second method begins with a definite result and seeks a satisfactory explanation. The method, as can readily be seen, only requires four experiments for finding the constants, n, k, and z, of Equation (12); one experiment on each side of the lower and upper critical points suffices to give the locus of all the points of the curve. If further experimental and mathematical work shows that the constants, n, z, and k, are computable, then it follows that it must be possible to separate the roughness coefficient, ϕ, of z, and evaluate it, and thus permit of microscopic research on the nature of the surface as related to its coefficient, which would doubtless throw much light on the nature of a roughness as applied to pipes.

Referring to Equations (17) and (18), where the approximate equations for n involve the coefficient, k, which contains μ^{-1}, or n is a function of μ and anticipating the conclusions of Equation (36) of Part II, where n is not a function of viscosity, it may be said that in the case of solids the field is unlimited and the turbulent motion set up gradually dies away by the damping action of viscosity, though, in the case of pipes, the field is limited and there is no such damping action; hence it is reasonable that both conclusions are correct.

Part II.—A General Formula for the Resistance to Flow of Fluids in Pipes or Channels.

The notation used is the same as in Part I, with such additions as are required. The centimeter-gram-second system of units is used throughout.

Preliminary Considerations. Three Stages of Flow Considered.

First Stage.—Below a certain critical or limiting velocity, the law of flow for any pipe or fluid is expressed very accurately by the equation

$$K_1 \ D^2 \ S = V\mu \dots\dots\dots\dots\dots\dots\dots (1)$$

Second Stage.—Between the foregoing limiting velocity and a still greater one, or the lower or higher critical velocities, is a region of flow concerning which but little is known. It has been recognized heretofore by writers and experimenters as a zone, or region, of disturbance. It will be shown that for any pipe there is a quite simple law of flow for this stage (hereinafter called the second stage), and that it is represented accurately by

$$K_3 \ S\mu = V^3 \dots\dots\dots\dots\dots\dots\dots (2)$$

Third Stage.—For all velocities above the higher critical velocity (end of the second stage), which is the case of ordinary use, or turbulent flow, there is no theory thus far developed except the empirical relation of

$$C \ R^{\frac{1}{2}} \ S^{\frac{1}{2}} = V \dots\dots\dots\dots\dots\dots\dots (3)$$

where the coefficient, C, is a variable. This is the oldest formula, and the efforts of hydraulicians have centered largely about correct values for the coefficient, C.

There is also the exponential type of equation

$$C \ R^y \ S^x = V \dots\dots\dots\dots\dots\dots\dots (4)$$

in which C is not constant and the exponents, y and x, are thus far not within the scope of prediction, but do represent the facts quite accurately, as determined experimentally.

Viscosity as a Factor.—Experiments show that the viscosity of the fluid affects the flow, and that in certain cases it is quite a notable factor, and cannot be disregarded; also, that its relation to the velocity is exponential, such that its consideration makes Equation (4) become

$$C \ R^y \ S^x = V\mu^z \dots\dots\dots\dots\dots\dots\dots (5)$$

Here C, again, has a new value, and is not a constant.

The Coefficient of Roughness, ϕ.—It has long been known that the surface condition of a pipe, or channel, influences the flow profoundly. Provisionally, this factor will be called ϕ, as in Part I,

leaving open the question of the nature of its experimental value as hereinafter found; that is, whether or not the value as experimentally found is the actual coefficient, or is some function of the actual coefficient.

Making R, m, and ϕ each equal to 1, then for a given pipe there can be written

$$C\,S = V^n \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

where C is a constant. Taking all known experimental data, it is seen that an equation of the form of Equation (6) corresponds most nearly to the data.

Logarithmic Co-ordinates.—Making log. S the abscissa, and log. V the ordinate, the exponent, n, of Equation (6) is found from the straight-line relation of

$$\frac{\log. S_1 - \log. S}{\log. V_1 - \log. V} = n \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

In general, it may be said that the experimental values of the exponent, n, for all the cases where any approach to accuracy has been made, ranges from $\frac{5}{3}$ to $\frac{6}{3}$, and never surpasses 2, in value. For the few cases where n has been found greater than 2, there is usually some abnormality. (This matter will be discussed later.) For flumes and channels, n never reaches the value of 2. To prove this, take the Kutter formula, as probably best expressing the law of flow, and assume only the variables present, such that

$$V = f x^n \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

and

$$\frac{1}{n} = \frac{V\,dx}{x\,d\,V} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

Make the Kutter coefficient of roughness, n, and the slope, s, constant, and let R be the above variable, x; then the formula can be written

$$v = \frac{A\,R^{\frac{1}{2}}}{1 + \frac{C}{R^{\frac{1}{2}}}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

Differentiating and reducing to Equation (9), it is found that the exponent, n, is

$$\frac{1}{n} = \frac{\frac{1}{2}}{1 + \frac{C}{R^{\frac{1}{2}}}} + \frac{\frac{C}{R^{\frac{1}{2}}}}{1 + \frac{C}{R^{\frac{1}{2}}}} \ldots\ldots\ldots\ldots\ldots\ldots (11)$$

from which it is seen that $\frac{1}{n}$ varies from 1 to $\frac{1}{2}$, between the limits of $R = 0$ and $R = \infty$, or the resistance varies as R^1 to R^2.

Making the slope, s, the variable in Equation (8), the formula becomes

$$v = \frac{A + \frac{e}{s}}{1 + \frac{C}{s}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (12)$$

from which, by Equation (9), the exponent is found to be

$$\frac{1}{n} = \frac{\frac{A\,s^{\frac{1}{2}}}{2} - \frac{b}{2\,s^{\frac{1}{2}}}}{A\,s^{\frac{1}{2}} + \frac{b}{s^{\frac{1}{2}}}} + \frac{\frac{e}{s}}{C + \frac{e}{s}} \quad \ldots\ldots\ldots\ldots\ldots (13)$$

which also makes the resistance vary as the first power when s is small and approaches the second power of V when s is large. Hence, in general, the Kutter formula can be expressed exponentially with the exponent of V ranging from 1 to 2.

From the foregoing it can safely be said that, for flow in the third stage, the resistance varies as V^n, with values of n ranging from 1 to 2, or, more closely, as far as is known for pipes conveying water, n ranges from $\frac{5}{3}$ to $\frac{6}{3}$ or more simply.

The third stage is characterized by the presence of a variable exponent, n, with $n > 1$ and $n < 2$.

Comparing the foregoing, with the deductions of Part I, there is seen to be the following order of succession of exponents:

	First stage exponent.	Second stage exponent.	Third stage exponent.
Solids	1	n	2
Pipes	1	3	n

As far as can be judged from the experimental data (which are far from complete), the transition from one stage to another is quite sudden or abrupt; or a very small increase in the driving force causes the foregoing changes in the exponents of the law of resistance.

Distinction of Boundary Conditions.—For the solid moving in an unlimited field of fluid, the maximum stream line disturbance is at the surface of the moving solid; and, due to viscosity, there is a damping

action which quickly reduces the disturbance to zero at no great distance normal to the axis of motion. For pipes, where the second or third stages are considered, there is quite a different law. The fluid friction created by the boundary conditions causes turbulent motion to prevail over the entire cross-section of the pipe, and the damping action named for the solids is absent. For the first stage there is a common exponent which points to a common law governing both, and it is probable that the law is a general one for all stages, the difference in boundary conditions producing the above changes in the exponents.

It will now be shown that there is a common law of resistance applicable to both solids and pipes, or that the general form of the equation applicable to solids, as given in Part I, can also be applied to pipes. There are certain elements which are common to both, such as velocity, diameter, viscosity, and fluid density. They differ in the choice of co-ordinates, V and D being used for the solids and V and S for the pipes, the Δ of the solids corresponding approximately to the S for the pipes.

As this part may be read by some who do not care to read Part I, the origin of the general equation will be fully set forth, and the same method of dimensions will be used.

The Method of Dimensions Applied to Find the Law of Flow for Pipes and Channels.—When generalized, the driving force required to overcome the frictional resistance of a pipe is seen to be the product of a volume, a density, and an acceleration (slope), or, in terms of mass, length, and time,

$$[L^3]\left[\frac{M}{L^3}\right]\left[\frac{L}{T^2}\right] = M\ L\ T^{-2} = \text{A Force} \ldots\ldots\ldots\ldots (14)$$

Opposed to the force and equal thereto is a resistance, which will here be assumed to be a product or function of a velocity, a diameter, a viscosity, and a fluid density, and the additional assumption is made that an exponential relation exists between these four factors, or, that

$$\text{Force} = k\,(V^x\ D^y\ M^z\ \phi^w) \ldots\ldots\ldots\ldots\ldots\ldots (15)$$

and the coefficient, k, is assumed to be a number not having dimension.

Equation (15), when fully written, becomes

$$[M][L][T^{-2}] = k\Big[[L^x\ T^{-x}]\,[L^y]\,[M^z\ L^{-z}\ T^{-z}]\,[M^w\ L^{-3w}]\Big] . (16)$$

Equating exponents, there is found from

$$\begin{aligned} &M, \quad 1 = z + w \\ &L, \quad 1 = x + y - z - 3w \\ &T, \; -2 = -x - z \end{aligned}$$

or, three equations containing four unknown quantities, which can be solved by assuming $n = x = y$ (or that V and D have the common exponent, n). Making this substitution, the resistance becomes

$$\text{Resistance} = k\ (V\ D)^n\ \mu^{2-n}\ \rho^{n-1}$$

from which the general equation can be written

$$k_n\ D^3\ S = (V\ D)^n\ \mu^{2-n}\ \rho^{n-1} \qquad (17)$$

This equation is practically identical with that of Part I for solids falling in fluids. Being perfectly general and homogeneous (that is, the sum of the exponents for mass, length, and time are equal in both members of the equation), it offers a sound basis or hypothesis from which to work. It may be objected that the assumptions made about the nature of a resistance are not proved to be true. To this may be said that the assumptions may be fairly considered as true, provided they accord with experimentally determined facts, and such proof will be given later.

The Reynolds Equation.—Professor Osborne Reynolds* proposed an equation for pipes of the form

$$\frac{A\ D^3\ i}{\mu^2} = \left(B\ \frac{D}{\mu}\ V\right)^n$$

in which A and B are coefficients, i is a slope, and μ a viscosity. This equation can also be written

$$A\ D^3\ S = (B\ V\ D)^n\ \mu^{2-n}$$

which differs only from Equation (17) in the absence of the density term, ρ^{n-1}, which is required to make the equation homogeneous and for other reasons shown later. Professor Reynolds' equation never came into use because of the difficulties of assigning proper values to the coefficients and the exponent. It will be shown that A and B are not constants, and, as before stated, n ranges in value from $\frac{5}{3}$ to $\frac{6}{3}$.

* *Proceedings*, Royal Society, 1883.

Special Values of the Exponent, n.—From Equation (17), by giving special values to n, there is found

$$\text{For } n = 1,\ K_1\ D^2\ S = V\ \mu \ldots\ldots\ldots\ldots\ldots\ldots (18)$$

$$\text{For } 1 = 2,\ K_2\ D\ S = V^2\ \rho \ldots\ldots\ldots\ldots\ldots\ldots (19)$$

$$\text{For } n = 3,\ K_3\ S = V^3\ \mu^{-1}\ \rho^2 \ldots\ldots\ldots\ldots\ldots (20)$$

Equation (19) is seen to be the basis of the Chezy formula.
Equation (20) can be modified to

$$k\ (S\mu)^{\frac{1}{3}} = V \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (21)$$

which form will be used later to find k and to test the general correctness of Equation (17).

Consideration of Equation (17) by Stages.—To test the accuracy of Equation (17) requires that it be applied to experimental data for the three stages, and, if it be correct, then it must agree with experimental results in all three stages.

The First Stage.—

$$K_1\ D^2\ S = V\ \mu \ldots\ldots\ldots\ldots\ldots\ldots\ldots (18)$$

For velocities below the lower critical velocity, that at the pipe wall is zero, and calling ϕ a coefficient of roughness, it is clear that flow in the first stage (or, $n = 1$) must be independent of ϕ, hence ϕ can only enter into the general equation with an exponent of $(n - 1)$, or, it is of dimensions the same as a density. Because both ρ^{n-1} and ϕ^{n-1} vanish when $n = 1$, it follows that k_1 must be a constant for any pipe or fluid, and its value is

$$K_1 = \frac{4\ V\ \mu}{D^2\ S} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (22)$$

From the ordinary theory of viscosity, it can be shown that in Equation (22) $K_1 = \frac{g}{8}$ or, on reducing,

$$\frac{g\ D^2\ S}{32} = V\ \mu \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (23)$$

Equation (23) is true for any pipe or fluid, and from it is deduced

$$\mu = \frac{g\ D^2\ S}{32\ V} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (24)$$

These equations show that all experiments on pipes in the first stage of flow are but experiments for finding the coefficient of viscosity.

and, given the latter, then the velocity can be predicted accurately by the use of Equation (23).

Applying Equation (23) to the reduction of the experiments of Messrs. Saph and Schoder*, which experiments bear internal evidence of having been made with great care, using the centimeter-gram-second system of units, and Slottes' formula for the coefficient of viscosity of water, there is found for their brass pipes:

Nos.	VII.	IX.	XIII.	XV.	XVI.
log. K_1....	1.4545	1.4830	1.4831	1.4760	1.4852
log. $\frac{g}{32}$.....	1.4866	1.4866	1.4866	1.4866	1.4866
Difference.	—0.0321	—0.0036	—0.0035	—0.0109	—0.0014

These pipes were not jacketed, nor is it known that the viscosity of the water used was that of distilled water; in the case of Pipe No. VII there is only one observation, where the observed loss of head was 0.0315 ft. The small departures noted above can readily fall under experimental errors.

Temperature Effects.—Examining in detail the data from "Brass Pipe No. XVI," there is found for the log. coefficients of K_1 the following values:

Experiment No. 101,	$t = 69.0°$	Fahr., log. $K_1 =$	1.4869,	Slope = 0.1829
" " 102,	$t = 69.5°$	" " "	1.4942	" 0.0780
" " 113,	$t = 70.4°$	" " "	1.4925	" 0.1172
" " 114,	$t = 70.9°$	" " "	1.4852	" 0.0586
" " 221,	$t = 75.2°$	" " "	1.4888	" 0.0897
Means	$t = 71°$	Fahr., log. $K_1 =$	1.4888	

The theoretical value is $K_1 = \log. \frac{g}{32} = 1.4866$.

The air temperature was about 68° Fahr., or nearly the same as that of the water used.

For lower temperatures, there are the following data:

Experiment No. 440,	$t = 38.5°$	Fahr., log. K_1	= 1.5026,	Slope = 0.337
" " 441,	$t = 38.4°$	" " "	= 1.5178	" = 0.191
" " 442,	$t = 38.3°$	" " "	= 1.5487	" = 0.072

* *Transactions*, Am. Soc. C. E., Vol. LI.

Assuming that log. K_1 is 1.4866, then to harmonize these observations requires changes in the wall temperature, as follows:

t 38.5° should be 40°, difference $= 1.5° \times$ slope $= 0.50$
t 38.4 " " 42°, " $= 3.6° \times$ " $= 0.68$
t 38.3 " " 46°, " $= 7.7° \times$ " $= 0.51$

or the correction required is roughly proportional to the velocity, a high velocity tending to absorb the heat derived from the air temperature difference of about 30° Fahr. These experiments show the necessity for protecting the pipe wall from external temperature changes.

Messrs. Barnes and Coker* have shown that, when a tube is heated from the outside, for velocities below the critical velocity, the heat affects only a mere film of fluid near the wall, as it passes through the tube practically unchanged in temperature. The observations of Messrs. Saph and Schoder are confirmatory of the fact that the surface film is affected. The writer has observed naked pipes in the oil fields of California, conveying oil by gravity, where a passing cloud obscuring the sun would cause a sudden drop in the flow. The action must have been at the pipe surface only, as there was not time to change the temperature of the mass of oil. It can also be inferred that the velocity must have been below the critical velocity. For the higher velocities, $n = \frac{5}{3}$ to $\frac{6}{3}$, it does not appear probable that ordinary differences of temperature could influence the flow greatly, because the water is eddying constantly against the sides and equalizing the temperature. From the foregoing it may be inferred that observations in the $n = 1$ stage are only useful to find the viscosity coefficient, μ, and that the same can be found with much accuracy, provided care is taken to avoid external temperature influences.

Reverting to Equations (22) and (23), it will be observed that their probable origin is from

$$D^2 \frac{\pi}{4} S = \left(\frac{8 \pi V D}{g} \right) \mu \quad \ldots\ldots\ldots\ldots\ldots\ldots (25)$$

The terms, $\frac{\pi}{4}$ and π, are the relations to area and surface, and the 8 is a constant belonging to the terms; it will be shown later that these terms must enter General Equation (17) as previously written.

* *Physical Review*, Vol. XII 1901.

The foregoing shows that General Equation (17) applies accurately to observations in the ($n = 1$) or first stage of flow.

The Second Stage of Flow.—The end of the first stage of flow (exponent $= 1$) is marked by a rather sudden change in the resistance from the first to the third power. This point is also the lower critical velocity. General Equation (17), making $n = 3$, becomes modified for this stage to its simplest form

$$k\,(S\,\mu)^{\frac{1}{3}} = V \text{........................} (21)$$

(Note that D disappears from Equation (21).)

Taking Messrs. Saph and Schoder's Brass Pipe No. XVI as a test, the limits of this stage appear to be between

Lower critical velocity, log. $S = 1.4912$, log. $V = 1.8563$
Upper " " log. $S = 1.8563$, log. $V = 1.9780$

and between these limits there are nine observations which, reduced for log. k in Equation (21), give

Experiment No.	99,	log. k	$= 2.6951$
" "	107	" "	$= 2.6971$
" "	109	" "	$= 2.6912$
" "	110	" "	$= 2.6946$
" "	111	" "	$= 2.7054$
" "	112	" "	$= 2.6805$
" "	218	" "	$= 2.6912$
" "	219	" "	$= 2.6871$
" "	317	" "	$= 2.6827$
Mean value			$= 2.6916$

When it is remembered that the experimenters were unaware that such a relation or stage existed, the foregoing very close concordance in the experimental values of the coefficient, k, is to be taken as an index of the care of the experimenters and also as highly confirmatory of the existence of a stage where the resistance varies as the third power of the velocity; at the same time, it confirms the accuracy of General Equation (17) by giving the proper exponent for the viscosity.

The remaining pipes, Nos. VII, IX, XIII, and XV, are not so regular in the values of the coefficient, the reason being that the data

for this region are less in number of observations, and also that some observations are either quite irregular or are too near the critical point. For these pipes the following are approximate mean values:

Pipe VII,	Mean log. k	$= 2.744$
" IX	" " "	$= 2.762$
" XIII	" " "	$= 2.692$
" XV	" " "	$= 2.721$
" XVI	" " "	$= 2.6916$

The Lower Critical Point.—According to Professor Osborne Reynolds, $\frac{V_c D}{\mu}$ = constant (about 2 000 when using the diameter and centimeter-gram-second system). It will be shown that this is only partly true. Writing the resistances and equating them for the common point, V_c, there is

$$\frac{V_c D \mu}{k_1} = \frac{(V_c D)^3}{k_3 \mu}$$

from which is found

$$\left(\frac{k_3}{k_1}\right)^{\frac{1}{2}} = \frac{V_c D}{\mu}$$

an equation which shows that $\frac{V_c D}{\mu}$ can only be a constant provided that k_3 is constant (k_1 is a constant), but the above values of k_3, which is the above k cubed, are not constant, which suggests that k_3 must contain $(\phi\ \rho)^2$, or $(\phi\ \rho)^{n-1}$, because it can be assumed that it is the roughness factor, ϕ, that determines the change in the law of resistance from V_c to V_c^3. For water, $\rho = 1$, hence ϕ^2 must be a factor of k_3, or $\phi^{\frac{2}{3}}$ is a factor of the k of Equation (21).

Consideration of k_n of Equation (17).—At this stage it is appropriate to consider the nature of the general coefficient, k_n, of Equation (17). From a study of the coefficients found in the three stages of flow, it became clear that k_n contains as factors, g^n, $\frac{1}{n\ (n-1)}$, $(S\ \pi)^n$, and $(\rho\ \phi)^{n-1}$. Further consideration of these factors, in connection with Equations (17) and (25), led to the following general form, which is Equation (17) more fully detailed:

$$D^3 \frac{\pi}{4} S = \frac{1}{n\ (n-1)} \left(\frac{S\ \pi\ V D}{g}\right)^n \mu^{2-n} (\rho\ \phi)^{n-1} \ldots\ldots (26)$$

in which form it may be considered as applicable to any fluid. If the constants, $\frac{8\,\pi}{g}$, are removed from the bracket, or are transposed to the left-hand member, then the term, ϕ^{n-1}, is no longer single-valued. The term $\frac{1}{n}$ is supposed to be an integration coefficient; the term, $\frac{1}{(n-1)}$, is also required to render ϕ^{n-1} a single-valued function, when $n = 3$ or n. Equation (26) can also be written

$$D^3 \frac{\pi}{4} S \frac{\rho\,\phi}{\mu^2} = \frac{1}{n\,(n-1)} \left(\frac{8\,\pi\,V\,D\,\phi}{g\,\mu}\right)^n.$$

In this form it is seen that the terms, μ^{2-n}, $(\rho\,\phi)^{n-1}$, do not have or require integration coefficients, other than the term, $\frac{1}{n\,(n-1)}$, common to both equations. From this it is seen that, for a given pipe in the third, or n, stage of flow, V varies as

$$\mu^{\left(\frac{2-n}{n}\right)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (27)$$

and temperature reductions are made accurately by using this exponent for μ. As an illustration, let $n = 1.75$, log. $V = 0.6000$, and $t = 35°$ Fahr.; required, log. V at $t = 70°$ Fahr.

	log. μ $t = 35$	2.2286	
	" μ $t = 70$	3.9878	
	difference =	0.2409	
$\frac{2-1.75}{1.75}$ =	$\frac{1}{7}$ difference	0.0344	
		0.6000	log. V at 35° Fahr.
		0.6344	log. V at 70° Fahr.

or 8.25% increase in the velocity from such temperature change.

Further Consideration of the Critical Points.—Making $n = 1$ and $n = 3$ for the first and second stages, using the final Equation (26), and equating resistances for the two stages and common lower V_c point, there is

$$\left(\frac{8\,\pi\,V_c\,D}{g}\right)\mu = \frac{1}{6}\left(\frac{8\,\pi\,V_c\,D}{g}\right)^3 \mu^{-1}\,\phi^2$$

from which is found

$$95.63\,\mu = V_c\,D\,\phi \ldots\ldots\ldots\ldots\ldots\ldots\ldots (28)$$

from which it is seen that $\frac{V_c\,D\,\phi}{\mu}$ = constant; and the statement of Professor Reynolds is modified by the introduction of the factor, ϕ.

The Upper Critical Point.—Making $n = 3$ and n, for the second and third stages, equating resistances for the common upper V_c point, by Equation (26), and reducing, there is found

$$\left(\frac{6}{n\ (n - 1)}\right)^{\frac{1}{3 - n}} \frac{g\ \mu}{8\ \pi} = V_c\ D\ \phi \ldots\ldots\ldots\ldots (29)$$

which shows the relations existing between the factors at the upper V_c, or beginning of the third stage.

As ϕ does not vary greatly for the brass pipes, the effect of both Equations (28) and (29), when using a logarithmic diagram and a common temperature, is to make both the lower and upper V_c points lie very nearly on a straight line, as noted by Messrs. Saph and Schoder.

From this it is seen that the factor, ϕ, is the determining cause of the change in the exponents; also, it can be inferred that the smoother and more regular the pipe wall the more sudden will be the change of exponents. Just why there is a change from the first to the third power in the resistance is not known, but the following is offered as a tentative solution.

Up to the lower V_c the fluid is assumed to be moving in parallel filaments, and there is no motion at the pipe wall. When the V_c point is reached, the motion is unstable and suddenly becomes turbulent, when the kinetic energy of the fluid is released and begins to expend itself in doing internal work which disappears as heat. As the kinetic energy is as V^2, this, by V, becomes V^3. Possibly in this case the kinetic energy might be represented (on a logarithmic diagram) by a triangle with a vertex at the upper V_c, all the surplus kinetic energy due from the lower V_c having been used up, and the new regime of $V^{n\text{th}}$ begins. This reasoning finds support in the fact that D^3 cancels out in both sides of Equation (26), thus showing that it is not dependent on the diameter, but on the kinetic energy present at the lower V_c. This stage, aside from its value as an easy method of finding the value of ϕ, when the pipe is not too large, would also have great value in finding the differential equation, on which Equation (26) must be founded.

Experimental Values of n, V_c, V, and ϕ.—Applying Equation (26), and using as exponents, 1, 3, and n, to the reduction of the experimental data of Messrs. Saph and Schoder, the following values are found:

Small changes in the value of the exponent are found, depending on the grouping of the observations. As these experiments extended over some time, it is seen that there are probably changes in the surface conditions of the pipes sufficient to produce a few hundredths in the value of the exponent. For the reduction given here, such values for finding n were used as were nearest in their numbers to those given for the $n = 3$ stage. Thus, for Pipe VII, Observations 56, 199, 201, and 388 were used for $n = 3$, and Observations 381, 382, and 383, with Observations 390, 391, 392, and 393, to find n; and for Pipe XVI, Observations 99, 107, 109, 110, 111, and 112, were used for $n = 3$, and Observations 103 and 104, with Observations 105 and 106, to find n.

TABLE 3.—VALUES OF n, ϕ, AND THE V_c POINTS.

Pipe No.	log. D	Exponent, n.	LOWER CRITICAL POINT $t = 70°$ FAHR.			UPPER CRITICAL POINT. $t = 70°$ FAHR.			INTERSECTION OF $n = 1$ WITH $n = n$, OR × OF FIG. 1. $t = 70°$ FAHR.		
			log. S	log. $V_c D$	log. ϕ	log. S	log. $V_c D$	log. ϕ	log. S	log. $V_c D$	log. ϕ
VII...	0.2042	1.7783	3.2492	1.3607	2.6417	$\bar{3}$.7089	1.5139	2.6441	3.0087	1.1202	2.6441
XVI..	1.4338	1.8263	1.4849	1.2852	2.6831	1.8512	1.4082	$\bar{2}$.6817	$\bar{1}$.3135	1.1138	2.6817

Table 3 shows a close agreement in the two values of ϕ found for the second and third stages, and it confirms the general arrangement of Equation (26), which is the only method found that makes ϕ of single value in the two stages.

To give a clear idea to those to whom the researches of Messrs. Saph and Schoder are not readily available, reference is made to Fig. 1, which shows the position on a logarithmic diagram of the three stages, $n = 1$, 3, and 1.794, for temperatures of 70° and 40° Fahr. These lines were obtained by Equation (17) and substituting therein the foregoing values of n, which gave the coefficients, k, k_3, and k_n; with these values, the intersection points, A, B, and C, D, were computed.

It will be noted that the point, C, is of much greater velocity than the point, A. Equation (28) shows that V_c varies directly as the viscosity. The equation shows that the $t = 40°$ or $C — D$ line is gen-

created by the motion of the $t = 70°$ or $A - B$ line along the line, $A - C$, which has a slope of log. $S = 2$, log. $V = 1$.

Log. Slope.

Point A = log. S = $\bar{1}$.4912	log. V = 1.8563	
" B = log. S = $\bar{1}$.8563	log. V = 1.9780	
" C = log. S = $\bar{1}$.8928	log. V = 2.0571	
" D = log. S = 0.2579	log. V = 2.1788	
70° log. viscosity	3.9877	
40° " "	2.1885	
Difference	= 0.2008	

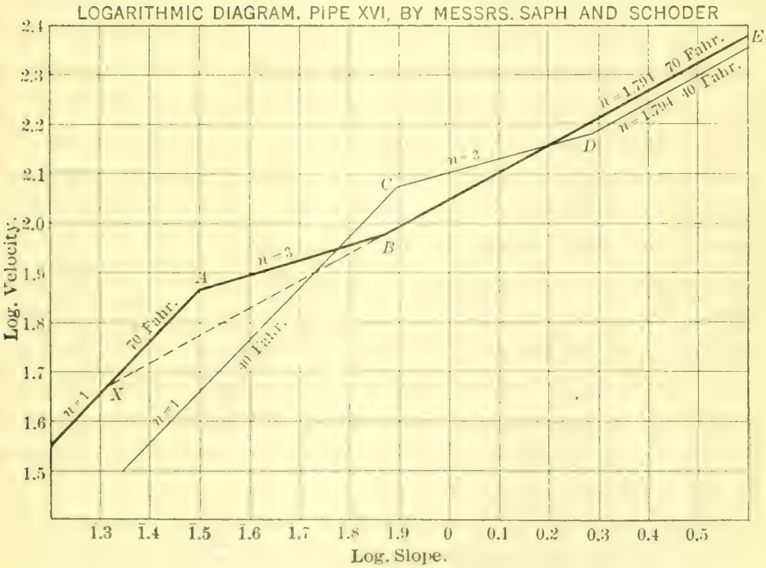


FIG. 1.

The Third Stage of Flow, V^n.—This stage is the most interesting from a practical viewpoint, as it is the one met in daily use. General Equation (26) represents quite accurately the experimental data, and it may be well to state here the method used to find the exponent, n, and the proof of the accuracy of the term, μ^{2-n}.

Calling *a.c.* the arithmetical complement, write a new equation, as follows:

$$x\ (a.c.\ \log.\ S) + \log.\ V - y\ (a.c.\ \log.\ \mu) = \text{Constant}\ldots.(30)$$

On the application of this equation to all the data of a given pipe above the upper critical velocity, the solution will be $x = \frac{1}{n}$, and y will equal a value very close to $\frac{2-n}{n}$; thus, for $n = 1.75$ to 1.80, small differences of 0.01 to 0.02 were found from the value of $2 - n$. Averaging all the data of Messrs. Saph and Schoder for their brass pipes, II to XVI, inclusive, it was found that the statement ν varies as $\mu^{\left(\frac{2-n}{n}\right)}$, is correct. Some larger differences than those above noted were found, and it seemed to point to progressive changes in the condition of the pipe surface. Those observations which were nearest to each other in time gave more concordant results than those found by comparing old and new observations. Differences in the exponent and also for ϕ were noted. The general impression left on the writer's mind was that, for purely experimental purposes, such as to discover the laws of flow, greater care must be taken with the experiments, possibly in the matter of jacketing the pipe, so as to have the wall temperature the same as the water moving in the pipe, and also that the water be quite free from sediment and bacterial or organic growths which might lodge on the rugosities of the surface, or could fill any pits in the surface, or, in the case of organic growths, might in a short time change seriously the surface condition to an extent detrimental to the accuracy of the experimental data sought. Filtration of the water and its sterilization would seem to be indicated as necessary requirements for any approach to accuracy.

Results Obtained by Equation (26).—Table 4 gives values of D, n, and ϕ, as found by applying Equation (26) to the reduction of some of the existing pipe data. With the exception of the experiments of Messrs. Saph and Schoder, most of the data lack details as to temperature. In order to make use of some of it, the temperature was assumed, as it seemed especially desirable to compare the exponents found for wood pipe with the corresponding values of ϕ for brass pipe.

Table 5 gives the viscosity coefficient, as used by the writer, to enable comparisons to be made by those to whom such tables are not readily accessible.

TABLE 4.—VALUES OF DIAMETER, EXPONENT, AND THE COEFFICIENT, ϕ.

Pipe No.	log. D. in centimeters.	Exponent n.	ϕ	Remarks.
SAPH AND SCHODER—BRASS PIPES.				
II	0.7202	1.7600	0.0445	
III	0.5803	1.7611	0.0476	
IV	0.5005	1.7540	0.0467	
V	0.4277	1.7547	0.0465	
VI	0.3185	1.7380	0.0456	
VII	0.2042	1.7618	0.0453	
IX	$\bar{1}$.9805	1.7749	0.0445	
XIII	1.7502	1.7417	0.0479	
XV	1.5885	1.7440	0.0444	
XVI	1.4338	1.7940	0.0466	

SAPH AND SCHODER—GALVANIZED PIPES.

Pipe		Exponent.	log. ϕ	
XVII direct	0.4214	1.9815	2.7110	
XVII reverse	0.4214	1.9353	2.7579	
XVIII direct	0.3342	1.8292	2.6840	
XVIII reverse	0.3342	1.8533	2.6673	
XIX direct	0.2014	1.8420	2.7513	
XIX reverse	0.2014	1.8676	2.7281	
XX direct	0.0914	1.9186	2.7348	
XX reverse	0.0914	1.9084	2.7457	
XXI direct	1.9489	1.9593	2.9061	
XXI reverse	1.9489	1.9302	2.9471	

Diameter, in inches.	log. D. in centimeters.	Exponent, n.	ϕ	Remarks.
E. A. MORITZ—WOOD STAVE PIPES, t ASSUMED AT 55° FAHR.				
55.75	2.1514	1.746	0.0610	
55.75	2.1514	1.757	0.0630	Year, 1909
22.00	1.7472	2.215	0.013	" 1910
18	1.6601	1.758	0.0582	
14	1.5509	1.863	0.0434	
14	1.5509	1.868	0.0399	" 1910
12	1.4840	1.749	0.1036	" 1909
8	1.3079	1.743	0.0538	
6	1.1830	1.794	0.0528	
6	1.1830	1.850	0.0508	" 1909
5	1.1038	1.896	0.0593	" 1910
4	1.0069	1.698	0.1144	

TABLE 4—(*Continued*).

Diameter, in inches.	log. D. in centimeters.	Exponent, n.	ϕ	Remarks.
J. S. Moore—Wood Stave Pipe.				
48.75...............	2.0928	1.778	0.0568	
31...................	1.8962	1.770	0.0598	
Desmond FitzGerald—Cast-Iron Pipe.				
48...................	2.0858	1.9696	0.0340	North pipe tuberculated.
48...................	2.0861	1.8787	0.0310	Cleaned.
Marx, Wing, and Hoskins.				
72.25...............	......	1.945	0.0410	Steel.
72.25...............	......	1.939	0.0300	Wood.
Clemens Herschel.*				
48...................	......	1.856	0.0702	
Clemens Herschel—Holyoke Conduit.				
103.38..............	......	2.08	0.0129	Iron.

* "115 Experiments," p. 27, Experiment 36, "Cylindrical Joints."

TABLE 5.—Common Log. of the Viscosity Coefficient,

$$\mu = \frac{0.017944}{(1 + 0.023121\ T)^{1.5423}}$$

(T = Centigrade degrees.)

t. Fahr.	log. μ	t. Fahr.	log. μ	t. Fahr.	log. μ	t. Fahr.	log. μ
32°	2.2539	48°	2.1287	64°	2.0233	80°	3.9321
33°	2.2454	49°	2.1216	65°	2.0172	81°	3.9267
34°	2.2369	50°	2.1146	66°	2.0112	82°	3.9213
35°	2.2286	51°	2.1076	67°	2.0052	83°	3.9160
36°	2.2204	52°	2.1037	68°	3.9993	84°	3.9110
37°	2.2122	53°	2.0937	69°	3.9935	85°	3.9060
38°	2.2042	54°	2.0871	70°	3.9877	86°	3.9011
39°	2.1963	55°	2.0805	71°	3.9819	87°	3.8962
40°	2.1885	56°	2.0735	72°	3.9762	88°	3.8914
41°	2.1807	57°	2.0674	73°	3.9705	89°	3.8866
42°	2.1731	58°	2.0609	74°	3.9649	90°	3.8806
43°	2.1655	59°	2.0545	75°	3.9593	91°	3.8758
44°	2.1579	60°	2.0481	76°	3.9538	92°	3.8709
45°	2.1505	61°	2.0418	77°	3.9483	93°	3.8662
46°	2.1432	62°	2.0356	78°	3.9428	94°	3.8615
47°	2.1359	63°	2.0295	79°	3.9374	95°	3.8568

Comparison of Equation (26) with the Usual Forms.—Calling C a variable coefficient which contains ϕ and μ, Equation (26) can be reduced to

$$C\,D^{\left(\frac{3}{n}-1\right)}\,S^{\frac{1}{n}} = V. \quad \ldots\ldots\ldots\ldots\ldots\ldots (31)$$

Making $n = 2$, Equation (31) is the Chezy form; otherwise it is the ordinary exponential equation as used by various writers. It was suggested by the late Charles H. Tutton, M. Am. Soc. C. E., and others that the sum of the exponents in the terms, D and S, are constant and equal to 1.17. This is only true when $n = \dfrac{3+1}{1.17+1} = 1.843$, or, their $R^{0.63}\ S^{0.54}$. Messrs. Saph and Schoder give for brass pipes $n = 1.75$, which is $D^{\frac{5}{7}}\ S^{\frac{4}{7}}$, or the same as their $D^{0.71}\ S^{0.57}$. Mr. J. S. Moore,* for wood stave pipes, gives $H = \dfrac{8.3\ V^{1.78}}{D^{1.20}}$, which is $1.78 + 1.20 = 2.98$, instead of 3, as required in Equation (31). As the sum of the exponents must be equal for each member of an equation, it is seen that when $n = 1.75$, then the C of Equation (31) requires an exponent of $\left(2 - \dfrac{4}{n}\right)$ or, -0.285, to satisfy the condition of equality of the sum of the exponents; which shows the futility of any attempts at precision unless the actual n, ϕ and μ be used, as set forth in Equation (26).

Recapitulation by Stages.—General Equation (26) is shown to apply quite accurately to the first stage ($n = 1$), and its derivative, Equation (23),

$$\frac{g\ D^2\ S}{32} = V\ \mu$$

is applicable to any pipe or fluid.

For the second, or V^3, stage, the general equation accords very closely with experiment. The change of the exponent of μ from $+1$ in the first stage, to -1 in the second stage, is brought out. By its use the apparently erratic observations of Messrs. Saph and Schoder over the critical region of flow are shown to accord quite closely with theory.

For the third, or the V^n, stage, the general equation makes use of the actual exponent, and also makes V vary as $\mu^{\frac{(2-n)}{n}}$, which form of exponent for μ agrees very closely with the experiments.

* *Transactions*, Am. Soc. C. E., Vol. LXXIV, p. 471.

Lastly, ϕ is a single-valued factor, with exponents of 2, and $(n - 1)$ in the second and third stages.

From which it can be said that the general equation found by dimensional methods is capable of satisfying all the known experimental data, and may be considered as correct.

The Exponent, n, and Roughness Factor, ϕ.—These are interdependent quantities, and, before any general use can be made of Equation (26), some method for their evaluation must be found. The general relation existing between these factors will next be discussed, and this will be followed by suggestions for further research work required for their definite evaluation.

The Relation of the Variables, n, ϕ, and V.—It has been shown that for $n = 1$, the coefficient, k, is $\frac{g}{32}$, a constant, and it is also clear that the diameter, D, and the viscosity factor, μ, can also be made constant, thus giving for the first stage a constant reference line, to which line the third stage can be prolonged, the intersection point being the foregoing V_0, marked X on Fig. 1. Although this point has no actual physical existence, it is a useful assumption, as it throws light on the genesis of $(n - 1)$. Making $n = 1$ and n, and equating resistances for each, as given by Equation (26), there is

$$\left(\frac{8\,\pi\,D\,V_0}{g}\right)\mu = \frac{1}{n\,(n-1)}\left(\frac{8\,\pi\,V_0\,D}{g}\right)^n \mu^{2-n}\,\phi^{n-1} \ldots . (32)$$

which reduces to

$$n\,(n-1)^{\frac{1}{n-1}} = \frac{8\,\pi\,V_0\,D\,\phi}{g\,\mu} \ldots\ldots\ldots\ldots\ldots\ldots (33)$$

Make $D = 1$, let μ be a constant (say for 70° Fahr.), and make $\frac{8\,\pi\,D}{g\,\mu} = 2\,b$, and Equation (33) becomes

$$n\,(n-1)^{\frac{1}{n-1}} = 2\,b\,V_0\,\phi \ldots\ldots\ldots\ldots\ldots\ldots (34)$$

Writing over each member of Equation (34) the equality $(n - 1)$, there is found

$$\frac{n-1}{n\,(n-1)^{\frac{1}{n-1}}} = \frac{n-1}{2\,b\,V_0\,\phi} \ldots\ldots\ldots\ldots\ldots\ldots (35)$$

The left-hand member of Equation (35) has the remarkable property that it is practically equal to $\frac{1}{2}$, as here shown.

Values of the Exponent and Function, n, of Equation (35).—

	$n = 2$	1.95	1.90	1.85	1.80	1.75
function	$n = 0.5000$	0.4965	0.4959	0.4990	0.5071	0.5231

Hence, for the usual range of exponents, $\frac{1}{2}$ may be written for function n, from which is obtained

$$(n - 1) = b\ V_0\ \phi \ldots\ldots\ldots\ldots\ldots\ldots\ldots (36)$$

an equation, very approximately correct, which can be made exact by using the proper value of function n instead of $\frac{1}{2}$.

Equation (36) shows that the term $(n - 1)$, or the fractional part of the exponent, n, is made up of a constant, into the limiting velocity, V_0, and the factor, ϕ, supposed to be either the absolute roughness factor, or a function of such factor.

Reverting to Equation (34), substitute for $(n - 1)$ the value, $b\ V_0\ \phi$, and there is found

$$(b\ V_0\ \phi)^2 + b\ V_0\ \phi = (2\ b\ V_0\ \phi)^{b\ V_0\ \phi} \ldots\ldots\ldots\ldots (37)$$

an equation which may serve to throw some light on the interdependent relations of V_0 and ϕ. If the assumption be made that the exponent, n, is never greater than 2, or that 2 is the upper limit for pipes and channels, which assumption appears to be true as judged by the facts, then it follows that a probable relation is

$$(n - 1) = b\ V_0\ \phi = \tan.\ h\ u \ldots\ldots\ldots\ldots\ldots (38)$$

where u might be considered some measure of the surface condition into $b\ V_0$, or

$$u = \frac{1}{2}\log._e \left(\frac{1 + b\ V_0\ \phi}{1 - b\ V_0\ \phi}\right) \ldots\ldots\ldots\ldots\ldots (39)$$

Concerning Equations (33) to (39), it is the writer's impression that any attempt at present to separate the variables would be useless, for the reason that there is now no method known of stating the numerical value of a roughness of a surface, and if the absolute value of ϕ, or such a roughness, could be deduced from existing data, it would still require further experimental work to connect such a value with a given surface.

For comparative purposes, four exemplars are here given. The mean value of V^n for some corresponding S, was reduced to $t = 70°$

Fahr., and using Equation (26) with $n = 1$ and n, the values of V_0 and ϕ were computed.

No. 1 is the average values for Messrs. Saph and Schoder's brass pipes, II, III, IV, V, VI, and VII, and Nos. 17, 18, and 21, are for their galvanized pipes.

No.	1	17	18	21
n	1.7547	1.9404	1.8286	1.9525
log. V_0	1.0766	1.1073	1.1115	0.9510
log. ϕ	2.6643	2.7497	2.6858	2.9111
log. $V_0\ \phi$	1.7409	$\bar{1}.8570$	1.7973	1.8621
log. u	1.9929	0.2409	0.0732	0.2691
log. $\frac{u}{V_0}$	2.9163	1.1336	2.9617	1.3319
Relative roughness	1.	1.65	1.11	2.61

The quantity, u, is the corresponding argument in a table of hyperbolic tangents that gives, $\tan.h\ u = (n - 1)$. It will be noted that for Nos. 17 and 21, $V_0\ \phi$ is nearly a constant, hence V_0 is some reciprocal function of ϕ. An inspection of its relation to the other quantities shows that it is probably transcendental and closely related to the relative roughness.

The last line, relative roughness, may be taken as an expression for the roughness, calling brass pipes = 1. It is this measure that is required in absolute measure, and its relation to V_0 and ϕ is required to effect the solution of Equation (36).

Probable Factors of the Exponent, n.—Equations (32) and (39) suggest the thought that the changes in the exponent for the three stages of flow have their origin in changes of boundary conditions, or certain limiting velocities combined with the surface condition, producing the observed changes, and, before proceeding to build up any theory of the cause of such changes, a brief review will be made of the possible contributing factors.

The Experimental Value of n.—For pipes and channels, our knowledge of the value of the exponent is derived from the relation

$$n = \frac{\log. S_1 - \log. S}{\log. V_1 - \log. V} = \frac{d \log. S}{d \log. V} = \frac{V\, d\, s}{S\, d\, V} \ldots\ldots\ldots (40)$$

General Equation (16) assumes that the resistance is a function of the surface, or that the surface condition determines the resistance

and its exponent, and Equation (40) shows that the exponent is found from a loss of head, and it should here be noted that there can be, and in practice usually is, loss of head not directly chargeable to the general surface condition, such as variations in diameter, as a cylindrical-jointed or a taper-jointed pipe; from the grosser inequalities of the surface, such as a row of rivet heads, circular or longitudinal, corrugations in the asphalt dip, large tubercles; any change from straight-line motion, such as bends in the pipe; leakage, air at the summits, etc. For all these abnormal conditions it is possible that the resistances follow some other law of exponent than that due to the general surface conditions, such as the resistance for the abnormal conditions might follow the V^2 law, or some law approximating it, and the normal resistance, such as is supposed to arise from a general surface condition, might be taken as the V^n law. This is a very important point, not heretofore recognized, and before any accurate advance in the theory can be made, means must be discovered for the separate evaluation of normal and abnormal losses of head.

As this paper is dealing with normal conditions, it will consider that the experimental results of the best selected data show that n ranges from $\frac{5}{3}$ to $\frac{6}{3}$ in magnitude.

The Exponent Increases with the Roughness.—Smooth pipes have exponents of 1.70 to 1.80, and rough pipes have exponents of 1.90 to 1.99 +, but do not reach the upper value of 2.

Velocity as a Factor.—The investigations of both Parts I and II, show that sudden changes occur in the value of the exponent, and that such changes are caused by, or at, a certain critical velocity, and that on a logarithmic diagram, the critical points are connected by straight lines from point to point. As far as can be judged from the examination of the data, the above-mentioned straight lines are not asymptotes, but the change appears to arise from a condition of unstable equilibrium, much like a balance just poised, when a very small addition to the weight will cause the beam to drop. It should here be remarked that the evidence on this point is by no means conclusive; thus, if careful experiments should show that the straight lines are really connected by a short curvature, it would necessarily modify the above-named opinion that the critical points are connected by straight lines, and might also modify the mathematical treatment of the problem.

Is the Diameter a Factor of the Exponent?—Equation (36) shows that the diameter is not a factor, because the b can be considered a constant; if some other diameter than unity be used, then the value of b would be correspondingly changed, with a simultaneous and equal change in V_0, or, $b_1 \, V_{01} \, \phi = b \, V_0 \, \phi = (n - 1)$. Table 4 shows that for brass pipes ranging from 0.1 to 2 in. in diameter, n and ϕ remain nearly the same through a range of 1 to 20; again, compare these brass pipes with the large wood stave pipes of Messrs. Moritz and Moore, where the exponents and ϕ are almost the same as for the brass pipes, or, there is practically the same n and ϕ through a range of 575 diameters, from which it may fairly be concluded that the exponent is independent of the diameter. A logical conclusion from which is, that, for the purpose of finding laws experimentally, a small pipe is more effective than a large one, because better control of all the details can be had.

The Exponent, n, is Independent of Viscosity.—The b of Equation (36) contains the viscosity factor, and, reducing all the experiments to a constant temperature, there still remain variations of V_0 and ϕ. Experimentally, this statement is confirmed as follows:

Fifteen brass pipes experimented with by Messrs. Saph and Schoder (see their Table No. 6) gave as a mean average value

$$\begin{array}{rr} t, 70^\circ \text{ Fahr. log. } \mu = 3.9877 & n = 1.7445 \\ t, 40^\circ \text{ Fahr. log. } \mu = 2.1885 & n = 1.7438 \\ \text{difference, } 30^\circ \text{ Fahr. log. } \mu = 0.2008 & n = 0.0007 \end{array}$$

or, a difference of 1.587 times in the value of the viscosity coefficient does not practically change the value of the exponent. Again, if, on a logarithmic diagram, the points having common temperatures and different velocities be connected, a series of parallel lines results. All of which shows that the viscosity factor is only a coefficient the exponent of which changes as set forth in Equation (17). The above paragraph is quite important in respect to the conclusions of the following paragraph.

Change of Exponent from a Change of Fluid.—Experiments made by A. M. Hunt,* M. Am. Soc. C. E., with 4- and 6-in. screwed steel

* *Journal of Electricity, Power and Gas*, January, 1905.

pipes, used for conveying crude oil from the Coalinga, Cal., oil field, gave for the values of n

$$4\text{-in. pipe, } n = 1.485$$
$$6\text{-in. pipe, } n = 1.132$$

Nothing was said about temperature or viscosity. A bulletin issued by the California State Mining Bureau gives for average Coalinga crude oil

Viscosity, t 15° cent., 3.09 times greater than for water.
" t 85° cent., 1.17 " " " " "

The only point desired to be brought out is that there is a very great change in the exponent due to a change of fluid. For water, these pipes would have had exponents of about 1.85 to 1.90. Assuming that the viscosity is three or four times greater than that for water, compare it with the more accurate data of Messrs. Saph and Schoder, where a difference of log. μ — 0.2008 gave a difference of only 0.0007 in the value of n. Accepting Mr. Hunt's data as substantially correct, some other explanation than that of greater viscosity must be had for such large changes in the exponent. One possible explanation is that it is due to some other property of the fluid molecule than viscosity, such as atomic weight, molecular diameter, mean free path, form of molecule, etc. As the atomic weight for oil is greater than for water, it appears that this property must operate to reduce the exponent. Provisionally, it will be called $(a\ t)$ and as such will appear among the probable factors of the exponent, n, as, $(a\ t)^{-z}$, the exponent $-z$, being introduced, as it is at present unknown. Direct experiment with different fluids would probably give a constant for each fluid of the form, const.$^{-1}$.

Possible Change of Exponent by Reversal of Flow.—This matter is somewhat uncertain, because, as previously stated, of the time that elapsed between experiments where there might have been progressive changes of the surface conditions, but, on the whole, the evidence points to such a change. It is conceivable that, in the process of manufacture of a pipe, the surface inequalities might have a greater average slope in one direction than another, or, this combined with the pattern arrangement might, on a reversal of the direction of flow, cause small changes in V_0 and ϕ, hence there would be changes in the exponent. At present, the information on this point does not warrant any fur-

ther notice than a general caution to future experimenters to consider the matter.

The Roughness Factor.—The inner surfaces of seamless brass tubing (which to the eye were quite smooth), when examined under a microscope having a power of 60 diameters, showed a surface which appeared to be covered with small wart-like masses separated by dark lines. No idea of their height was gained. The diameters varied from 0.002 to 0.004 cm., with an average of about 0.0035 cm. Galvanized pipes were more irregular. A pipe 1 in. in diameter had one side of about the same degree of roughness as that of the iron from which the zinc had been stripped. The other side was far rougher, and was quite drossy; elongated tears of zinc showed that this was probably the bottom side while draining. The average diameter of the roughnesses was from 0.01 to 0.02 cm., averaged at 0.016 cm. A ½-in. galvanized pipe was quite smooth, and nearly comparable to the brass pipes. A ⅜-in. galvanized pipe was found to be rough and angular, with a quite different grouping from the others. The average diameter was about 0.01 to 0.02 cm., and it was apparent that the rugosities were of greater height. It was the writer's impression, from this cursory examination, that by using photo-micrographs (or other suitable methods), the differences noted could be expressed in definite terms, and perhaps correlated with the exponent. It was made quite clear that there are minute differences which affect the exponent and coefficient, ϕ, and are not visible to the unaided eye.

On a Definition of a Roughness.—At present, the only means of expressing the degree of roughness its adjectival. In default of exact knowledge, the terms, rough, rougher, etc., are used, when what is really required is a definite numerical value, as an essential to any further advance. The foregoing examination seems to indicate that there is a possibility of obtaining a numerical definition by noting the average number of rugosities per unit surface, their mean height, and general cross-section. In addition to these general features, it is probable that the pattern arrangement might be such as to influence the stream-line motion of the fluid.

Broadly stated, a numerical definition would consist of the average departure from a perfect surface, combined with complete knowledge of the form and arrangement of an average departure, which in turn suggests the following as measurable quantities:

N_2, the number of rugosities per unit surface.

h, the average height of the rugosity.

It is possible that this might be sufficient for practical purposes, but for scientific purposes, a further classification might be required, such as,

θ, an average angle of one rugosity with the pipe axis.

λ, an average angle of rugosity to rugosity referred to the pipe axis (pattern arrangement).

The two latter factors would certainly be required if there should be found that the succeeding paragraph is a necessary factor of flow.

General Remarks on Turbulent Flow.—Exploration by Pitot tubes of the velocities over the area of a pipe in turbulent flow shows that the velocity near the wall is about one-half of that at the center of the pipe, and the mean velocity is about 0.68 of the radius from the center, the central and wall velocities being joined by a parabolic or elliptical curve. This statement, taken singly, implies that the central part of the fluid tends to run away from the fluid nearer the wall, or a state of non-diffusion must exist. Opposed to this view are the actual experiments of Benzenberg, Campbell, and others, where dye, bran, etc., have been used to measure the mean velocity, the underlying principle being, that there is such diffusion, accompanied by translation, and that after a long run, the marking material may still be considered as a fairly compact body, which serves as an accurate measure of the mean velocity. Such experiments taken singly show an active circulation across the pipe, in some manner, by which the marking substance diffuses transversely, but not longitudinally.

The experiments of Reynolds show that the beginning of turbulent motion is a spiral flow of the marking substance. From all three statements it is probable that the fluid motion is checked at the wall, diffuses toward the center, and then returns toward the wall; at the same time it is subject to longitudinal translation. Hence it is not improbable that the mean motion is at the same time spiral; or, all fluid molecules tend to rotation about the pipe axis. Hence it follows that Pitot tube measurements must be those of one component of the mean motion, the actual velocity of the moving fluid being greater and generally at an angle with the pipe axis. It thus appears that

the actual motion or average velocity of a point may be something quite different from the mean flow or resultant of all the points.

There is a marked difference between the stream-line motion of a solid moving in a fluid and that of a fluid moving in a pipe, and it should be expected that the nature of the stream function should be different. For the case of turbulent motion (or exponents of resistance greater than one), the maximum disturbance of the fluid molecule must be near the moving solid and due to viscosity; this motion is damped and completely dies away at some distance normal to the axis of motion. In the case of turbulent flow in a pipe, there is no such damping action. All the molecules are disturbed in varying degree over the entire area of the pipe section.

If the foregoing assumption of a mean spiral path of a particle be correct, then the mean motion is periodic, and a given particle would tend to reappear more or less in the same place measured around the pipe, the recurring points separated along the pipe axis by a period of one complete rotation. One particle, however, must react on the next nearest to it, and, in the supposed case of general spiral motion, it is not improbable that there might be superposed on the general spiral path an oscillatory motion, also periodic in its nature, the latter motion probably corresponding to a dissipation of energy function and the former to a stream-line function.

At present, nothing is known of the actual motion in a pipe, and the foregoing paragraph is only suggestive of a factor that may require estimation for the complete development of Equations (32) to (36). For the actual inquiry, it seems that by the use of a glass pipe carrying fluid charged with opaque particles of about the same density, and the use of a camera traveling at the mean velocity, it would be possible to record accurately and trace out the path of one or more opaque particles.

Recapitulation.—The initial stage of flow has 1 for exponent, and it suddenly becomes n, hence the problem is to find the cause of the addition of $(n - 1)$. Collecting from the preceding discussion the possible factors of $(n - 1)$, there is found in the order given, the following list of probable factors of $(n - 1)$:

a, magnitude, ranges from $\frac{2}{3}$ to 1;

b, roughness, ϕ increases with the roughness;

c, critical velocity, V_0, dependent on a definite velocity;

d, change of fluid ($a\ t\ ^z$); profoundly changes ($n - 1$);

e, possible change by reversal of direction of flow;

f, possible change due to stream and dissipation function.

Some additional remarks on some of these six factors are in order.

a.—Assuming Equation (26) to be correct, if it is applied to data where n is greater than 2, there results improbable values for ϕ. For example, in Table 4, the 22-in. wood stave pipe has $n = 2.215$ and $\phi = 0.013$; also, the Holyoke conduit, 103.38 in., $n = 2.08$ gives $\phi = 0.0129$. Judging by the remainder of the pipes, where n is from 1.74 to 1.95, these values of ϕ are probably about one-fourth to one-fifth of the real value. In general, both n and ϕ increase simultaneously. Here there is a decrease in ϕ with a great increase in n. For this reason, as well as that all the more exact experiments of Messrs. Saph and Schoder show values of n less than 2, it is believed that Statement *a*, is correct. It should be remembered that on the correctness of the statement ($n - 1$) is 0 to 1 depends the nature of the function connecting the variables ($n - 1$), $\phi\ V_0$.

b.—This statement is in accord with general experience. The microscope measures of rugosity previously cited are also confirmatory. Although no great accuracy is claimed for such measurements, it will here be assumed that the following approximate relations exist, or sufficiently so for a comparison:

Seamless brass pipe, diameter of a rugosity 0.0035 cm., $n = 1.75$, $u = 0.975$.

Galvanized pipe, diameter of a rugosity 0.014 cm., $n = 1.92$, $u = 1.59$.

Where ($n - 1$) = tan.*h* u, and taking logs.,

log. diameter	3.544	log. u 1.989
" "	2.146	" " 0.201
difference	0.602	0.212

From which there is sufficiently exact

$$6.5\ (\text{diameter of rugosity})^{\frac{1}{3}} = u \ldots\ldots\ldots\ldots\ldots (41)$$

$$\text{or}\quad \frac{6.5}{N^{\frac{1}{6}}} = u \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (42)$$

where N denotes the number of rugosities per square centimeter. It is not affirmed that Equations (41) and (42) are correct. They are

only suggestive of some relation between the diameter of a rugosity and $(n - 1)$, which by Equation (42) would be

$$\tan.h\left(\frac{6.5}{N^{\frac{1}{6}}}\right) = (n - 1) \ldots\ldots\ldots\ldots\ldots\ldots(43)$$

in which the 6.5 probably is a function of $(n - 1)$, V_0, and the mean height of a rugosity.

c.—As the critical points on a logarithmic diagram seem to be connected by straight lines, this seems sufficient to justify the statement that such lines are not asymptotes, but rather point to a condition of unstable equilibrium, which is the cause of the sudden change from one stage to another. Additional experimental work about the actual V_c points is needed to clear up the present uncertainties as to the precise cause of the change. Such work is also required to choose the proper form of function to connect the variables. The experiments indicate that V_0 and V_c are inverse functions of the absolute roughness. Concerning the suddenness of the change of stage, such a change may be considered as the integration of all the separate resistances caused by an average rugosity, and it seems probable that the more regular the surface the more sudden the change. Great irregularity might tend to changes before and after the V_0 or V_c point, with the result of a slight curvature connecting the branches; hence, experiments with burnished pipes are desirable to test this view and at the same time find some minimum value of n.

d.—Experiments with different fluids, especially with those having molecular constants which are best known, offer the opportunity to vary the exponent while using a given surface, which would doubtless throw much light on the problem. Conversely, the method would be applicable in chemical physics to clear up doubtful points as to molecular properties.

e.—This may be viewed as a special case of *b* where the arrangement of the rugosities differs for direct and reverse motion.

f.—From a study of the relations of $(n - 1)$, V_0, and ϕ, it seems probable that some additional function is present and that ϕ of Equation (26) is not strictly a roughness function but probably is of compound nature, hence the introduction of the stream function and dissipation function as possible factors. Such factors would certainly be functions of the roughness.

Summary.—The foregoing shows that there is one primary factor, the roughness, with V_0, V_c, and $(n - 1)$, dependent functions, and probably the stream and dissipation functions also dependent functions. Hence, the solution of the problem resolves, as a first step, into the formulation or definition of a roughness, and the assignment of a numerical value therefor.

Assuming temporarily, that ϕ is such numerical value of the roughness factor, and make λ a stream-line factor, it appears probable that the problem would be about as follows:

$$u = a\ \phi\ V_0\ \lambda\ (a\ t)^{-z} \dots\dots\dots\dots (44)$$

and

$$\tan.h\ u = (n - 1) \dots\dots\dots\dots (45)$$

For water, the term, $(a\ t)^{-z}$, would be constant, and could be dropped by giving a new value to a. The experimental work required to find the value of ϕ would simultaneously give V_0 and $(n - 1)$. λ, if required, would probably have to be deduced by mathematical methods, as it is undoubtedly dependent on ϕ and V_0.

Suggested Experiments.—Among the prime requisites for the final solution of the values of $(n - 1)$, V_0, and ϕ, might be named:

The use of clean or filtered and sterilized fluid. This would prevent changes of the surface condition and give a higher degree of accuracy to the constants thus found. Experiments could be repeated with considerable time interval if found necessary, with the certainty that the surface is unchanged.

Jacketing the pipe to avoid temperature changes.

The use of small pipes of at least two different diameters.

The use of burnished pipes, where the utmost degree of smoothness would be attained.

The use of threaded pipe, lead pipes, for example, having screwed surfaces. This would ensure a uniform condition of wall surface. The threads could be varied to any extent in pitch and cross-section of thread, and could have the thread of unequal section for direct and reverse flow. This method admits of great variations, is easily carried out, and would directly relate a given surface to the sought variables by means of exactly known surface conditions. By the change of fluid in the pipes mentioned, new values would be found for the variables.

By the use of photo-micrographs of actual surfaces, combined with such other measurements as might be practicable. It is probable that some definite numerical coefficient could be assigned to such surface.

After such work, would follow appropriate mathematical treatment of the acquired data, which, if not leading directly to the solution of the problem, would indicate the nature of any required additional experiments.

The writer is aware that the belief is held by some that it is doubtful if any better methods than those now used will ever be found, because of the manifold variations of the surface condition. From this belief the writer vigorously dissents. The present degree of knowledge of such surfaces is practically zero. When all the factors of the surface condition are studied and classified, a new world of information will be available, and thus narrow down the range of exponent and coefficient, if not to exactness, at least sufficiently close for practical use.

With these suggestions, the writer submits the paper, to hydraulicians and those interested in the subject, for criticism and discussion, and trusts that some of the hydraulic laboratories will take up the remaining work outlined herein, and find a complete solution of the problem.

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A STUDY OF ECONOMIC CONDUIT LOCATION.*

By C. E. Hickok, Assoc. M. Am. Soc. C. E.

The paper entitled "Economic Canal Location in Uniform Countries,"† by Lyman E. Bishop, Assoc. M. Am. Soc. C. E., contains a series of interesting and useful diagrams, by the use of which the locating engineer can quickly determine the economic center line cut for any particular canal section for any slope of ground. However, every conduit, unless it is in a country of uniform topography, must change at certain points from one type of construction to another, in order to be built economically and safely. It is rarely that a conduit of any considerable length can consist entirely of canal section, but rather it must change to flumes, siphons, pipes, bridge flumes, or tunnels, as the conditions demand. The points of change are determined, not only by the slope of the ground, the nature of the material encountered, and certain local conditions, but by economic considerations as well.

In making conduit locations, from time to time, the writer has evolved a diagram, giving the equivalent lengths, from an economic standpoint, of various types of conduit, which has been of considerable value. For instance, when the locator comes to a point where he must decide whether to tunnel through a ridge or follow the grade around with a canal, he measures the length of the two possible routes, and, by an inspection of the diagram, comes to a ready decision. This not only eliminates considerable loss of time, but, if the diagram has been properly constructed, assures a proper and complete comparison between

*This paper will not be presented at any meeting, but written communications on the subject are invited for subsequent publication in *Proceedings*, and with the paper in *Transactions*.

†*Transactions*, Am. Soc. C. E., Vol. LXXIV, p. 179.

the two alternatives as to first cost, depreciation, head-loss values, evaporation and seepage loss values, interest, taxes, inspection, and repairs.

For purposes of illustration assume a case where the project under consideration is to be used for irrigation and hydro-electric purposes, and where the conduit has a capacity of 44.6 cu. ft. per sec. and a slope of one-tenth of 1 per cent. Four types of conduit are shown in Fig. 1.

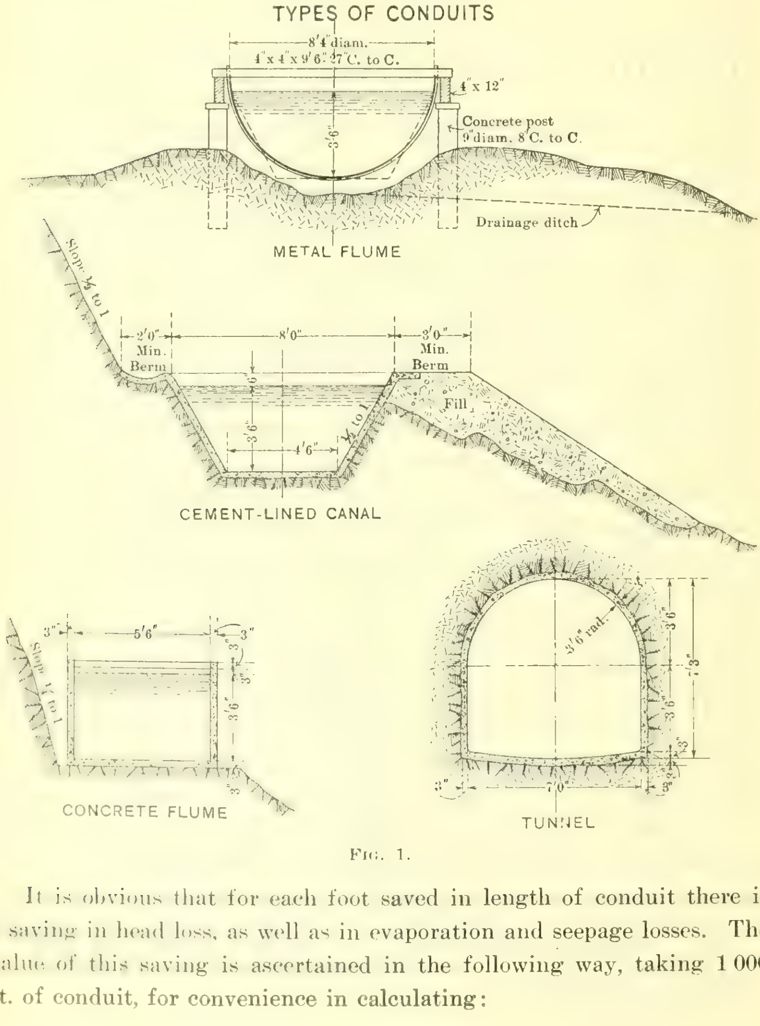

Fig. 1.

It is obvious that for each foot saved in length of conduit there is a saving in head loss, as well as in evaporation and seepage losses. The value of this saving is ascertained in the following way, taking 1 000 ft. of conduit, for convenience in calculating:

Head Loss.—1 000 ft. of conduit dissipates 1 ft. head. With a discharge of 44.6 cu. ft. per sec., and 77% efficiency, the horse-power is

$$\frac{1 \times 44.6 \times 62.5 \times 0.77}{550} = 3.9 \text{ h.p.} = 2.8 \text{ kw.},$$

less 10% for transmission and transformer losses = 2.61 kw. at $55 .... $143.50

Evaporation Loss—Power Value.—Assuming an evaporation of 5 ft. per annum:

$$\frac{8 \times 1\,000 \times 5.0}{43\,560} = 0.915 \text{ acre-ft. per year}$$

= 0.0025 acre-ft. per 24 hours = 0.00125 cu. ft. per sec. with a head of 1 500 ft.,

$$\frac{0.00125 \times 1\,500 \times 62.5 \times 0.77}{550} = 0.162 \text{ h.p.} = 0.121 \text{ kw.},$$

less 10% for transmission and transformer losses = 0.109 kw. at $55 .... $6.00

Seepage Loss—Power Value.—From tests made by Elwood Mead, M. Am. Soc. C. E., and B. A. Etcheverry, Assoc. M. Am. Soc. C. E., at the University of California, the writer concludes that the rate of percolation through a 3-in. canal lining under a head of 3.5 ft. is about 0.0043 ft. per hour, or 0.103 ft. per 24 hours.

$$\frac{8 \times 1\,000 \times 0.103}{43\,560} = 0.0188 \text{ acre-ft. per 24 hours}$$

$$= 0.0094 \text{ cu. ft. per sec.}$$

$$\frac{0.0094 \times 1\,500 \times 62.5 \times 0.77}{550} = 1.23 \text{ h.p.} = 0.92 \text{ kw.}$$

less 10% = 0.828 kw.,

0.828 kw. at $55 .... $45.54

Total annual power loss	$195.04
Capitalized at 10%	$1 950.40
or per foot	1.95

Evaporation Loss—Irrigation Value.—0.0025 acre-ft. in 24 hours (from the foregoing) = 0.00125 cu. ft. per sec. = 0.0625 miner's inch. Assume 25% loss before delivery to consumer:

0.047 miner's inch at $0.40 per miner's inch per day = per annum	$6.86
Seepage Loss—Irrigation Value.—0.0188 acre-ft. per 24 hours (from the foregoing) = 0.0094 cu. ft. per sec. = 0.47 miner's inch, less 25% loss = 0.353 miner's inch at $0.40 per miner's inch per day = per annum........................	51.64
Total annual irrigation loss...........................	$58.50
Capitalized at 10%..................................	585.00
or per foot..	0.585

Résumé.—

Power loss per foot......	$1.95
Irrigation loss per foot..	0.585
Total loss per foot....	$2.535

The first cost and the annual charges of each type of conduit are next computed. The annual charges are taken as consisting of the following items: interest, depreciation, taxes, inspection, and repairs. The annual charges of each conduit are capitalized at 10% and added to its first cost, which gives a figure having a real comparative value. For instance, we obtain the comparison between a lined canal and a concrete-lined tunnel as follows:

CONCRETE-LINED CANAL:

First Cost—Per Foot.—	Excavation, 2 cu. yd. at $0.36.	$0.72	
	Concrete, 4.25 cu. ft. at $10.20 per cu. yd................	1.57	
			$2.29
Annual Charge.—	Interest at 10%..................	$0.23	
	Depreciation at 2%..............	0.046	
	Taxes	0.019	
	Inspection	0.01	
	Repairs	0.02	
		$0.325	
	At 10%		3.25
			$5.54

CONCRETE-LINED TUNNEL:

Excavation, 2.25 cu. yd. at $5.50		$12.40	
Concrete and forms		4.10	
			$16.50
Annual Charge.—Interest at 10%	$1.65		
Depreciation at 1%	0.165		
Taxes	0.137		
Inspection	0.01		
Repairs	0.02		
		$1.982	
At 10%			19.82
			$36.32

It is evident, if we shorten the conduit by building the tunnel, that the first cost and the capitalized annual cost of the tunnel can exceed the first cost and the capitalized annual cost of the canal by an amount equal to the length of conduit saved multiplied by the loss value per foot of conduit. This is shown by the equation:

$$Y\ (C_y + A_y) = X\ (C_x + A_x) + (x - y)\ V$$

where X = linear feet of canal,

Y = linear feet of tunnel,

C_x = estimated cost per foot of canal,

A_x = estimated annual charges per foot of canal capitalized at 10%,

C_y = estimated cost per foot of tunnel,

A_y = estimated annual charges per foot of tunnel capitalized at 10%,

and V = value of losses per foot of conduit.

In the case of a tunnel, the evaporation will be considerably lessened, thereby effecting an additional saving. If entirely eliminated, this saving would amount to 12.8 cents per ft., as shown above. This was reduced to 10 cents and the first cost of tunnel credited with that amount. Inserting the proper values in the equation:

$$Y\ (16.40 + 19.82) = X\ (2.29 + 3.25) + (x - y)\ 2.53$$

$$Y = 0.208\ X, \text{ the equation of a straight line.}$$

In the same way, any two types of conduit can be compared and the resulting straight-line equation obtained. The diagram, Fig. 2, which is self-explanatory, shows the results.

GENERAL FORMULA

$$y(C_y) = x(C_x) + (x-y)V + x(A_x) - y(A_y)$$

C_y = Estimated cost per foot of conduit above line

A_y = Estimated annual expense per foot of conduit above line capitalized at 10%

C_x = Estimated cost per foot of conduit below line

A_x = Estimated annual expense per foot of conduit below line capitalized at 10%

V = Estimated value of one foot of canal for power and irrigation purposes = $2.53

Tunnel is credited with 10 cents per foot for saving in evaporation.

VALUES USED

	Original cost per foot	Annual expenses per foot
Tunnel	$16.50	$1.98
Concrete-lined canal	2.30	0.325
Concrete Flume	4.28	0.579
48" Steel siphon 100' head	5.88	0.961
48" Steel siphon 200' head	7.46	1.211
48" Steel siphon 300' head	10.64	1.714
Steel Flume	5.58	0.887

Steel siphons are credited with $1.10 per foot for saving in evaporation and seepage.

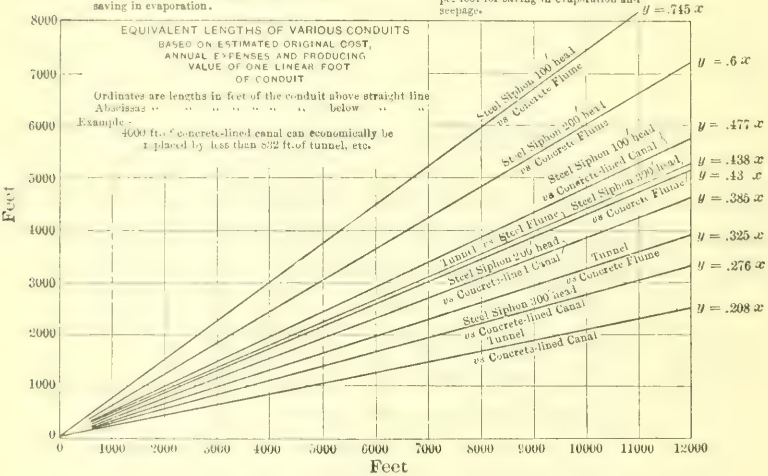

FIG. 2.

In the case where a siphon crossing a gulch is compared with a canal or flume passing around the head of the gulch, the cost of the siphon is credited with the saving in evaporation and seepage throughout its length, which in this case amounts to $1.10 per ft.

The writer realizes that such a diagram cannot be relied on entirely in the location of a conduit, for there are local conditions on every piece of work which must be taken into account.

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PHYSICAL VALUATION OF RAILROADS.

Discussion.*

BY MESSRS. STEVENSON TAYLOR AND WILLIAM J. WILGUS.†

STEVENSON TAYLOR, ESQ. (by letter).—The general principles involved in covering methods of determining valuations of railroads, with the attendant matters of bookkeeping, establishment of costs, and the important subject of depreciation, have been considered by the author with admirable thoroughness, and the writer has no good reason for differing from his conclusions. Mr. Taylor.

If we hope to encourage "men fitted by experience, acquaintanceship, resourcefulness, courage, and tact," as well as investors large and small, so that the building, extension, and upkeep of railroads may proceed further to advance the interests of the whole country, we must deal justly with this broad question of public utility and with those who are and who may become directly interested therein.

The author has pointed the way. There may be differences as to minor details, but his paper covers the subject in a masterly manner and with fairness and justice to all concerned, including the general public.

WILLIAM J. WILGUS, M. AM. SOC. C. E. (by letter).—The writer has a deep sense of obligation to those who have kindly participated in the discussion of his paper, as many of his own ideas have been clarified by the additional light that thereby has been cast on the subject. Mr. Crehore has generously credited him with an absence of desire "to complicate valuation work, and to seek out every possible pretext for making the assets, both tangible and intangible, look as big as possible"; and to this the writer feels that he may conscientiously reply that, in preparing this paper, he has had absolutely no Mr. Wilgus.

* Continued from November, 1913, *Proceedings*.

† Author's closure.

Mr. Wilgus. other purpose in mind than an attempt to place his own views where they may be freely criticized by his fellow members and others, all in the interest of straight thinking.

Unlike Mr. Crehore, the writer does not believe that the *bona fide* stockholder as a class "gets something for nothing," nor that the stockholder is an "incumbrance." The fact that a small group of financiers may have abused the confidence and trust of innumerable innocent, if too confiding, investors of small means, seems in fairness to be no reason why experienced engineers should not attempt to formulate principles for guiding a valuation of property capitalized at some $20 000 000 000, for purposes that in the end may crystallize into a move for Government ownership.

Surely, Mr. Crehore would not ask that the subject shall be approached other than dispassionately in the hope that correct principles of valuation may be adduced, and that the facts as to any improper past return to the investor through interest and dividends and reinvested income, shall be then studied and a fair decision reached in the case of each road. Broad generalizations as to inordinate profits to investors in public utilities can hardly fail to do an injustice to a large proportion of the public that in good faith has invested amounts, great and small, in enterprises from which the entire public has reaped the enormous benefits referred to by Mr. Churchill.

In this connection it will be well to bear in mind that an approval of the theory that reinvested surplus and increases in land values are to be viewed as additional income to the stockholder, necessarily carries with it the proposition that such additional income is entitled to a return. This admitted, the accrued re-investments and other increases in value constitute a sinking fund, made up of equal annual payments compounded at the rate of interest to which the service is entitled, for the full period of accumulation. For instance, an increase in 60 years of $100 000 000 in the value of a property, due to the increments mentioned, is equivalent to $187 572 annually, compounded at 6 per cent. This annual sum, added to the average annual dividends and interest actually disbursed in a given time, will produce the figure that should be taken as the total past annual return to the owners of the property in both cash and "kind". The point that the increment, if interpreted as income in an analysis of past results, is entitled to a return, has been missed by many. A similar error has been made by those who would count the increment as an additional return to the owner, and at the same time brand it as a depreciation reserve.

Several, notably Mr. Eaton, have expressed regret that the broader social problems of the day have not been touched on in the paper. The writer has felt that the subject of the valuation of railroads should be treated concretely, with a definite end in sight—the logical method

of arriving at physical values and that the manner in which the result should be used is a separate matter for independent discussion. The treatment of the so-called unearned increment, including donations from the community and reinvested surplus out of questionably excessive earnings of earlier years, is a question on which few as yet agree, and until the views of the majority are expressed through legislation that will affect all kinds of property alike, it does not seem equitable that one class of investment should now be selected for retro-active action. The correct course would appear to lie in making an appraisal that will stand the acid test of analysis, and then from a study of the past condition of each property make such disposition of the unearned increment as will be in consonance with a similar attitude toward other classes of property. Mr. Wilgus.

Mr. Gillette speaks of the supplanting of the competitive theory of railroad ownership with the agency theory, under which the public utility continues to be financed by the owner, but is indirectly managed by the Government through public regulation. The writer believes that this dual and contradictory relationship can be but temporary, the next logical step being nationalization. The enforcement, by the Interstate Commerce Commission and similar bodies, of expenditures for improvements on railroads will make obligatory the raising of new money by the owners through the sale of bonds or other form of prior obligations, and this in time will materially reduce or wipe out the stockholder's equity. If this final step to Government ownership is inevitable, it would seem better for the stockholder to encourage the transfer while he still has something to sell, that is, before his equity has been legally confiscated.

The contributors to the discussion by no means agree on the principle that should be adopted in determining physical value. Messrs. Churchill, Crehore, Gandolfo, and Gillette see the practicability of ascertaining the original costs from the books or the amount of cash actually invested, while Messrs. Coombs, Humphreys, Ingersoll, Lavis, Molitor, Thomson, and Whinery join with the writer in considering this course to be generally impracticable. An intimate acquaintance with the records of many corporations, large and small, has demonstrated to the writer that the obtaining of correct, full, original-costs-to-date is so generally impossible that the use of that method would work wide injustice. No doubt there are some instances where book costs have been carefully kept so as accurately to reflect every item of expense chargeable to capital account, including organization, legal and administration expenses, interest during construction, and freight on construction materials, as well as all additions and betterments, with their proper burden of overhead charges; but the exceptions are so numerous that the use of a substitute method would be imperative, with the result that all roads would not be treated alike.

Mr. Wilgus

An objection that has been raised to the alternative for original-cost-to-date, namely cost-of-reproduction, is the inclusion therein of the increment of land values. Many contend that railroads, being public utilities, should not profit by the increment which is freely conceded to private individuals and corporations of another character. The justice of this contention is not apparent, as there are no laws in force for the guidance of investors in public utilities, which differentiate on this point between the two classes of ownership, nor is such contention upheld by the tax authorities, as forcefully pointed out by Mr. Aldrich.

That any other than the reproductive theory will produce inconsistent results will be seen in the following case, which is illustrative of a situation that is very common.

Of three railroads running near each other through the same territory, Line A was built 30 years ago and has partial records of original-cost-to-date, Line B was constructed recently, and has complete and accurate records of cost, and Line C, built 15 years ago, has no records of cost whatever. If the original-cost-to-date principle is adopted, the recently-built Line B, having full records, will be treated equitably; but Line A will suffer through incompleteness of data and loss of the increment of value that is contained in the estimate for Line B, and for Line C, possessing no records, the estimate cannot be determined by the adopted principle, and, therefore, must be arrived at by some other method which will be inconsistent with that used for the rival lines. On the other hand, if the reproductive principle is adopted, all roads will be treated exactly alike, and the older lines will not be placed at a disadvantage in comparison with the last built road.

Many endorse the reproductive method in theory, but in practice propose modifications that destroy the principle. The estimating of the cost of land at the same price as neighboring property, sometimes termed the basic or normal price, ignores the facts set forth by Messrs. Aldrich, Howard, and Whinery, that land for railroad purposes actually costs in excess of such price, and that the exclusion of a part or all of the overhead costs leaves out of the estimate elements which are as essential to the creation of a railroad as scaffolding in the building of structures. The omission of these items of cost is not in accord with either the original-cost-to-date theory or the reproduction method. Estimating in this manner has not the merit of following clearly any theory that will stand analysis, and is contrary to the experience of those who are familiar with the keeping of book costs or the actual building of railroads.

It has been said that reproductive estimates provide for "what it will cost to buy again land that will never be bought again, to duplicate property that will never have to be duplicated, and to build

up a business that will never again have to be developed." Is not this the course that necessarily has to be followed in arriving at the value of any going concern, the earning power of which may not be used as the measure of its value? The appraiser of the physical value of a factory would base his estimates on a duplication of the plant, including the present-day reproductive value of its lands, structures, and cost of delevopment. What would be necessary in a simple instance of this kind is just as necessary in the case of a railroad. Mr. Wilgus.

Referring particularly to the matter of lands, and using the previously quoted illustration, Line A will be found to have paid for right of way 30 years ago, say, \$600 per acre, and the modern Line B will have paid for land of precisely the same character, say, \$1 500 per acre, or three times the basic value of neighboring property which in large blocks sells at an average of \$500 per acre. The original-cost-to-date principle will give Line A \$600 for exactly the same kind of property which, in the case of Line B, will be valued at \$1 500; and Line C, having no records, will have its land valued by some differing method. The basic method will give Line A \$500 for that which cost it \$600 30 years ago, Line B will be credited with \$500 for that which cost it \$1 500, and, again, will Line C require some alien treatment. The reproductive method would give all three roads the same price for the same character of land, would work no injustice by confiscation, and would give to the two older lines the same values that are embodied in the cost of the new rival.

In the Minnesota Rate Case, the United States Supreme Court ruled in favor of the basic-price method, but the comments of the Court on the testimony of the chief witness on land values give hope that a new presentation of the subject will lead to a future modification in this regard.

Many instances may be cited where railroads in recent years, under Court decrees in condemnation cases as well as by private purchase, have paid several times the amounts that would result from the use of the basic or neighboring-value method; and it is evident that the use of the method prescribed in the Minnesota Rate Case would work confiscation to many roads and entirely discourage the creation of new ones.

Mr. Crehore's proposal that all owners of property shall fix the value of their holdings as a basis for taxation and sale has its attractive side, but the benefits which he anticipates in the acquiring of lands for public utilities at minimum prices, would hardly materialize, in view of the question of severance and other damages that would still remain for settlement. That the property owner voluntarily should place a higher valuation on the part of his holdings through which he might imagine a railroad would be likely to pass, is crediting him with a degree of prophetic vision and engineering skill that is un-

Mr. Wilgus. possessed by the average man; and the payment of excess taxes on such a product of his imagination would be to him a costly venture from which the chance of repayment would be, to say the least, exceedingly remote.

The question of how to handle depreciation has developed two widely divergent views. Messrs. Eaton, Gillette, Humphreys, Ingersoll, Lavis, Molitor, Taylor, and Waitt, and, to a limited degree, Mr. Whinery, believe with the writer that no deduction therefor should be made from the cost of reproduction new, and Messrs. Brinkley, Coombs, Crehore, Gandolfo, Nicolaysen, and Willoughby think otherwise.

It is possible that this difference of opinion is to a large extent due to a failure by each side to grasp the reasons that are guiding the other; and a somewhat extended dissertation on the subject may be pardonable, illuminated as it is by the ideas brought out in the discussion.

Depreciation of railroad property, as generally understood, consists of physical retrogression, due to usage and decay, and to lessened effectiveness through obsolescence and inadequacy.

This physical retrogression calls for two classes of expenditures, namely: (1) current maintenance applied to those items which need constant attention in the ordinary upkeep of road and equipment; and (2) deferred maintenance of features that cannot be economically restored, renewed, or replaced until they reach maturity.

Sound practice, enforced by the rules of National and State regulatory commissions, requires that expenditures for both current and deferred maintenance of public utilities shall be charged to operating expenses, and not to capital. Stated differently, depreciation is declared to be an item of expense to be defrayed from the rate, and not wastage of capital to be paid for through the issue of securities.

A well-run corporation will maintain its property so that current repairs and renewals will not be allowed to fall behind, and it will also regulate its distribution of dividends to stockholders so that the combined depreciation reserves and profit and loss surplus will be not less than the accruals of deferred maintenance. In this connection it should be added that the profit and loss surplus of a railroad company is just as much a reserve fund for offsetting depreciation as if so labeled.

A failure thus to provide for these two classes of depreciation is usually the result of over-payment of dividends, and eventually brings its own punishment through the necessity of a reduction or suspension of dividends during the period of rehabilitation. This course is obligatory, as charges for rehabilitation legally can only be made through income.

It will thus be seen that stockholders who unwisely or improperly overpay themselves in dividends, are simply creating a liability that must be repaid through a lessened later return on their investment. They are not, as Mr. Crehore states, in the position of "eating their cake and having it too," for the reason that they must restore the "cake" from their own resources; they are prohibited from doing so through capital account. Mr. Wilgus.

If this line of reasoning is correct, the investor is entitled to a rate sufficiently large to: (*a*), defray operating expenses, including current maintenance and taxes; (*b*), provide an allowance for deferred maintenance; and (*c*), yield a fair return on the investment unimpaired by depreciation; with the understanding, however, that if the allowance for deferred maintenance is not properly conserved, its restoration shall be effected from the investors' return which otherwise would be available for dividends. In other words, (*a*) and (*b*) are preferred obligations.

All this brings us back to the proposition that, under the law, physical depreciation of both classes, current and deferred, is a stockholder's liability and not a wastage of capital, and, consequently, it should not be deducted from the investment in determining a question of rates.

The railroad is a very complex organism, and the question of depreciation is correspondingly involved. A more simple illustration may assist in clarifying the subject.

The owner of a ferry-boat is admittedly entitled to a rate that will produce earnings sufficient to pay operating expenses, including all repairs, renewals, and taxes, and, say, 6% on the investment. By gouging out and restoring each spot of rot or wear as it appears, and replacing each nail or bolt the moment that it commences to chafe or rust, the boat may be maintained practically new for an indefinite period; and in that event no question would be raised as to the owner's title to the full 6% return on the unimpaired investment, as there would be no depreciation. But this method of repairing, being very costly and, therefore, adverse to public interest, it is considered better practice to confine current repairs and minor renewals to those parts which may be repaired economically from day to day, and pay at regular intervals into a deferred maintenance sinking fund an amount which, with accumulations at compound interest, will produce a sum at the end of a given period with which to restore the old boat or purchase a new one. Can it be fairly said that in the latter case the return on the investment must constantly fall from 6% on the full amount when the boat is new, to zero at the date of restoration or replacement; whereas, in the former case, so much less to the public interest, the full rate should continue without abatement? If so, it would seem far better for

Mr. Wilgus. the investor to abstain from the common carrier field, and loan his funds in a manner that will guarantee the same rate of return without confiscation of principal.

It is admitted by many that the arguments for the non-deduction of depreciation are well taken in cases where an ample reserve has been accumulated in outside investments, as in the ferry-boat example, and in cases where the property has not been enriched through improvements paid for from income; but the claim is made that in instances of physical valuation where no such outside reserve or other assets exist, and funds for off-setting depreciation have been reinvested in the improvement of the property in the shape of additions and betterments, there is a clear inequity in permitting a return to the owner on the portion of the property so reinvested. The answers are: First, that the impracticability of drawing lines sharply between improvements paid for through capital and others paid for from income, makes imperative the adoption of some rule that will apply uniformly to all; second, that the methods of accounting established by the Interstate Commerce Commission prohibit the practice which would become necessary of charging repairs and renewals to capital, if items originally appraised in their depreciated condition later were raised to their restored value; third, that the treatment of past additions and betterments as the equivalent of additional income to the owner removes those items from the category of depreciation reserves; and fourth, that on the owner rests the continuing duty of replacing depreciation out of the allowed rate, making good from his own share thereof any deficiencies due to over-payment of dividends or other diversions of the part of the rate intended for current and deferred maintenance.

Many are the instances which may be quoted of a reduction or suspension of dividends from the latter cause. Railroads thus situated could not increase their rates as a means of rehabilitating their properties, and have been forced to forego a full or even partial return on the investment until the necessary repairs and renewals had been effected out of what otherwise would have been distributable to the stockholders. Certainly, neither sound financing nor the accounting rules of the Interstate Commerce Commission, would sanction the capitalizing of expenditures for rehabilitation; nor would the laws of competition or the rules of regulatory commissions permit a raise of rates to accomplish the same purpose.

Not only from the standpoint of logic does it appear that in questions of rate regulation, depreciation should not be deducted from the principal, but also, as a practical matter, this course seems to be the only one to adopt. Current maintenance fluctuates during the year so that what may be a fair estimate in one month is unfair in another month. For instance, in the fall the depreciation on ties

in the railroads of the United States amounts to some $60 000 000 less than a few months earlier in the year prior to the commencement of annual renewals. Costly structures, if estimated at a depreciated value, later will be found to have been rebuilt or replaced, with a corresponding large increase in value. To add these growths in value, through restoration of depreciation, to a previously determined capital sum, in effect would amount to a capitalization of items which, under the law, had been charged to expenses—a course that speaks for unsettled rates as well as a violation of accounting principles established by the Interstate Commerce Commission. Then, too, the annual revision of depreciation, unlike additions and betterments, cannot be recorded through book entries, but necessarily must be effected through a recurrent field inspection of the multitude of items that enter into the construction of railroads, a truly monumental task. There is the further point raised by Mr. Molitor, that what is deemed to be a depreciated condition for high-class traffic may be as good as new for a less exacting service. Moreover, the adoption of depreciated values, with their shortened lives, would call for the inclusion in the rate of higher percentages of depreciation than would be necessary were the same objects estimated at their cost new, and this would practically nullify the saving to the public of using depreciated values as a basis for fixing the investor's return. Mr. Wilgus.

The recent disastrous flood damage in the Middle West is a good illustration of the matter at issue. Railroad property was depreciated to the extent of many millions of dollars, all of which had to be restored out of earnings and profit and loss surplus, without an increase of capital on which rate-payers would be expected to defray the interest. Surely, it would not be equitable to impose a further burden on the stockholders by a lessened return on the depreciated investment at the very time when they are compelled to forego a part of their savings or profit in meeting their liability to restore their property to full working condition. To do so would amount to a double burden on the stockholders through a wastage of capital and reduction of earnings or surplus.

May it not be said, therefore, that in questions affecting rates, the desirability of avoiding constant fluctuations of rates, compliance with the accounting rules established by public regulatory commissions, the avoidance of confusion and needless complications, and sound logic, all point to the correctness of the claim that the value of railroad property should be considered unimpaired by depreciation; and that on the stockholder rests the obligation of restoring depreciation, either from profit and loss surplus or "reserves", or through a lessening of the return on his investment during the period of rehabilitation.

Mr. Wilgus. It is true that the United States Supreme Court, in the recently decided Minnesota Rate Case, did not take this view, but may we not conclude that this was the result of an inadequate presentation of the principles underlying this important question rather than a final endorsement by the Court of the general proposition that, in matters affecting return on capital, depreciation should be deducted from the investment.

The claim has been made that if the appreciated value of right of way and real estate is allowed, a deduction for physical depreciation is entirely proper. This does not seem to be a logical contention, for the reason that the appreciation of land values, being an additional return to the investor, plainly should be credited to capital account; while depreciation is of a physical nature caused by temporary retrogression, and is a charge to expenses and not to capital account.

On the very important item of overhead charges there appears to be little difference of opinion among those discussing the paper.

Beyond question, as brought out by Mr. Gillette, the percentage for contingencies should be comparatively small if reliable data as to quantities and up-to-date costs are obtainable from the records; but where estimates are necessarily made without the benefit of such precise knowledge, and the adopted unit prices are not inflated, a sufficiently liberal allowance for contingencies should be made, precisely as would be done by the experienced engineer in preparing preliminary estimates for any project. It has always seemed to the writer that the item of contingencies should be provided for through a percentage that will be open to inspection and discussion, rather than through an arbitrary increase of unit prices where it would be more or less concealed.

Mr. Gandolfo considers that no provision should be made for the educational stage during which construction gradually draws to a close, and traffic is built up from nothing to the full volume on which the income that may be in question is earned. With an object so simple as an automobile, the dealer devotes his time gratis to educate a customer and to the repair and replacement of any defective or imperfect parts, before the transaction is closed; and the cost of labor and materials for thus breaking in the car and educating the user is contained in the price. So, too, with a railroad, must certain expenses be provided for in the estimated cost of reproduction, for breaking in the plant, and educating the forces which are to supervise the moving of the existing volume of traffic. A railroad's operating organism does not spring, Minerva-like, into being, fully equipped and trained for a complicated service; it must pass gradually from the period of active construction to the culmination in growth of the going concern; and, as Mr. Lavis points out, it is by a

suitable allowance for interest charges that this going value may be measured. Mr. Wilgus.

In the organization of the valuation corps largely rests the success or failure of the outcome of a physical valuation. Beyond question, the qualities mentioned by Mr. Gillette are desirable, and, in most instances, essential; but the one feature which he omits, experience, would seem to be the prime need, if the results are to stand. This is particularly mentioned by Mr. Waitt. The chiefs of field parties certainly should have the very qualities that Mr. Brinkley would not credit to them, capacity and experience for observing and recording the condition of the property.

As stated by Mr. Molitor, a low-grade line through a populous country has a distinct advantage over a competitive high-grade line through a sparsely settled region; but with net earnings, in which the rate at issue is a factor, eliminated as a measure of such advantage, the selection of some other yardstick of intangible values is a problem on which no light has yet been shed. The writer has purposely abstained from suggesting a measure for such intangible values as traffic productivity and operating effectiveness, because he has been unable as yet to define in his own mind just how they may be estimated, other than for comparative purposes under known local conditions.

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FLOOD FLOWS.

Discussion.*

By Messrs. Herbert E. Bellamy and E. Kuichling.

Herbert E. Bellamy, Assoc. M. Am. Soc. C. E. (by letter).—This paper is most interesting and well worthy of a place in the *Transactions* of the Society. The problems associated with the great rivers of America, and the great forces of Nature brought into operation by the enormous rainfalls of that country, spread over great catchment areas, are subjects of much interest to engineers. The writer is sure that those resident in Australia especially will be very thankful to the author for his valuable paper, and also for the lucid manner in which he has presented it. From a careful perusal, it would seem, to those studying the question of the discharge of rivers in flood times, that the tabulated statements submitted by Mr. Fuller, comparing one river with another, supply information which has long been needed. This comparison is of great value. It suggests a method which is simple, and at the same time possesses certain elements of mathematical precision and many indications of accuracy which will be exceedingly helpful to those who write on the subject. Mr. Bellamy.

The rivers of Australia are few and small compared with the size of the Continent, and are subject to two serious and opposite disadvantages—they are swollen to overflowing or are practically dried up so as to be unnavigable. The area of Australia is 2 950 000 sq. miles, and the only river within this great continent that can be compared for size with those of the Old and New Worlds is the Murray. The basin of the Murray comprises about 414 253 sq. miles, or about one-seventh of the whole. This area includes 104 525 sq. miles of Queensland, 234 362 sq. miles of New South Wales, 50 979

*Continued from November, 1913, *Proceedings*.

Mr. Bellamy. sq. miles of Victoria, and 24 384 sq. miles of South Australia; but, of the total area of the basin, only 158 499 sq. miles make any effective contribution to the volume of the river, the scanty rain which falls on the remainder of the area being quickly absorbed. The average rainfall over the whole area is only 13 in. per annum.

Of the rivers which flow to the east, the two most important are the Fitzroy and the Brisbane. On the north coast, the largest rivers are the Flinders, which falls into the Gulf of Carpentaria, and the Victoria, which falls into the Queen's Channel. On the west coast, the best-known rivers are the Ashburton and the Swan.

The misfortune of Australia, as regards rainfall, is that the mountain ranges, which act as condensers, lie so near the east coast. The result is that the narrow coastal plain gets more rain than it needs, and, when the rain-bearing winds from the Pacific have crossed the mountains and table-lands into the interior, the great heat there dissipates the clouds and does not permit them to condense into rain.

In attempting to form a rule for flood discharges for Australian rivers, it will be found that there are as many exceptions as there are rivers, and further that the flood discharge in each river varies according to the precise locality in which it is measured. The writer considers that the question of the fresh-water floods of Australian rivers in relation to the areas and physical features of their basins is one of those multiform problems which can only be solved by special attention to the peculiar circumstances of each particular case. One of the chief wants experienced by the water engineer in Australia arises from the scantiness of reliable data regarding the occasional floods to which the rivers especially, and parts of the country generally, are subject. There is probably much valuable information in the hands of a few engineers now engaged on public works throughout the country, but, except in one or two cases, it has never been collected for reference. In any case there is great difficulty in securing reliable evidence of the levels attained by great floods which occurred more than 40 or 50 years ago. This difficulty has been found by the writer on several occasions when desiring to fix permanent levels for new pumping stations to be constructed on the banks of rivers in connection with town water supplies. In one case, for Rockhampton, on the Fitzroy River, he deemed it advisable to fix the engine-house floor level 3 ft. above the maximum flood level, although flood records were available for a period of 47 years. Records of the heights of various floods in this river have been tabulated by the writer.*

On the eastern coast the flood discharge of a river is greater per square mile for relatively small drainage areas than for larger ones, because of the greater intensity of precipitation on the former in time of storm.

* *Minutes of Proceedings*, Inst. C. E., Vol. CLXIII.

The author states that: "In studying the data, a few rivers, located principally in arid and semi-arid regions, were eliminated on account of unusual conditions." Mr. Bellamy.

It is more especially to these latter conditions, in so far as they pertain to a few of the Australian rivers, that the writer wishes to direct attention. From even a cursory examination of Table 34, and the brief description of the physical characteristics of Australian rivers, it will at once be apparent that it would be impossible to establish a set of coefficients applicable for Australian conditions.

The Murray rises, as the Indi, in Pilot Mountain, 5 000 ft. above sea level, and, receiving a large number of tributary mountain torrents fed by the snows of the Muniong and Bogong Ranges, flows swiftly down from the table-land on the lower plain, falling 4 500 ft. in its first 300 miles. Toward Albury it is joined by the Mitta and Kiewa, and, between Albury and Wentworth, the affluents of the Murray are the Ovens, Goulburn, Campaspe, and Loddon from the south, and the Murrumbidgee and Darling from the north. The fall of the river from Albury downward varies from 9 to 4 in. per mile. From Wentworth, however, to Lake Alexandrina, the fall is only 3 in. per mile. Lake Alexandrina has an area of 288 sq. miles, and the outlet for the Murray is through the Goolwa and Coorong Channels, which unite at Mundoo Island, and form one channel to the sea. The mouth of the Murray resembles many of the Australian bar-bound coastal rivers, and proposals have been made from time to time to make it navigable; but, on account of the formidable and costly difficulties to be encountered, nothing has yet been done.

The Goulburn River is the largest and most important Victorian tributary of the Murray. This river, which flows into the Murray at a point 880 miles from Morgan, and 676 miles from the South Australian boundary, for the twelve years ending with 1903, inclusive, had a maximum discharge of 37%, a minimum of 16%, and a mean of 23%, of the discharge at Morgan. The mean monthly discharge was from 30 to 70% in 1884, and from 21 to 62% in 1887, of that of the Murray at Echuca, which is 10 miles below the junction. The description of the Upper Murray is, in many respects, applicable to this river. It takes its rise in the Dividing Range, near Wood's Point, where the summits reach an elevation of 5 000 ft. The drainage area is about 9 000 sq. miles, about 1 500 sq. miles being in mountainous country of considerable elevation. This portion of the catchment area is rocky and precipitous, and a large proportion of the rainfall is discharged. The winter volume of the river is large, and the melting snows maintain the discharge far into the summer. About 5 200 sq. miles of the total catchment are effective, the remainder being non-contributing. The term, Goulburn Valley, is limited, by popular

Mr. Bellamy. usage, to the plain which extends from the Town of Murchison northward to the Murray.

The Lachlan River possesses a reputation for irregularity of flow which is, perhaps, not paralleled by any other river in Australia. As illustrative of the great fluctuations which take place in the volume discharged by the river, the records for 1900 and 1902 might be quoted. In July, 1900, a sudden downpour of rain, aided by melting snows in the ranges forming the upper portion of the Lachlan gathering ground, caused the river to rise from 19 ft. to 46 ft. 8 in. in 26 hours at Cowra. The estimated discharge at this height was 1 800 000 cu. ft. per min. This volume was maintained for nearly two days, after which the river gradually subsided to its normal level. The total discharge for July, 1900, exceeded 19 000 000 000 cu. ft. The flood of 1894, although not at any time reaching the maximum recorded in July, 1900, was more sustained, as the river was in flood for four months of the year, and in that period no less than 66 600 000 000 cu. ft. passed the gauging station. By way of comparison, it may be mentioned that this was 60% more than the volume discharged by the Murray at Albury for the whole year 1902. During the drought year, 1902, the Lachlan was practically a chain of waterholes, and the discharge for the twelve months only reached 1 024 000 000 cu. ft., of which a very small proportion passed Condobolin.

The Brisbane River has a total water-shed of about 5 300 sq. miles, the areas of the principal contributing rivers and creeks, respectively, being as follows:

Stanley River	600 sq. miles
Brisbane River, above Cooyar Creek	166 " "
Mousildale and Avoca Creeks	190 " "
Cooyar Creek	410 " "
Emu Creek	380 " "
Maroughi and Anduramba Creeks	180 " "
Cressbrook Creek	230 " "
Lockyer Creek	1 160 " "
Bremer River	780 " "
Remainder (about)	1 370 " "

This area is bounded on all sides by mountain ranges varying in height from 1 000 to 4 000 ft. More than 2 500 sq. miles in the upper portions of the water-shed consist generally of impervious strata, and the lower portions, or remainder, of permeable strata. The Stanley River, rising in high lands near the Pacific Coast, is subject to intense rainfall which has a quick run-off; indeed, so much so, that it is considered the chief factor in studying flood flows in the main river. The total length of the Brisbane River is 210 miles; it is tidal for 53 miles, and navigable for vessels of more than 12 000 tons as far as Brisbane.

Mr. Bellamy.

TABLE 34.

Name of river.	Situation of gauging station.	Maximum Annual Volume Passing Gauging Station.		Minimum Annual Volume Passing Gauging Station		Maximum Recorded Discharge per Minute.		Minimum Recorded Discharge per Minute.		Catchment area, in square miles.	General remarks.
		Cubic feet.	Year.	Cubic feet.	Year.	Cubic feet.	Year.	Cubic feet.	Year.		
Murray........	Albury	264 383 000 000	1894	41 091 000 000	1902	3 214 000	1880	17 500	Feb. 1903		
Murray........	Mildura......	1 141 728 000 000	1870	57 517 000 000	1902	6 000 000	1870	14 400	Apr. 1903		
Murray........	Morgan......	1 067 000 000 000	1890	105 000 000 000	1902	4 000 000	1890	44 500	Apr. 1903	......	There are no means of estimating the proportion of rainfall discharged by the Murrumbidgee, as the records do not include the highest peaks of the Dividing Range, where the heaviest falls of rain and snow occur. Gaugings from 1885.
Murrumbidgee	Hay.........	400 000 000 000	1894	18 500 000 000	1902	762 000	1894	12 000	Feb. 1903		
Lachlan	Forbes	92 600 000 000	1894	1 024 000 000	1902	1 800 000	1870	2 000 (mean only)	1902	20 159	Only in times of high flood that the waters of the Lachlan reach the Murrumbidgee. Ceased to flow 9 months in 1902.
Darling........	Wilcannia...	717 000 000 000	1890	700 000 000	1890	....	....	....	......	......	From February, 1902, to January, 1903, the river ceased to flow on account of the drought. Gaugings from 1885
Goulburn......	Murchison...	168 000 000 000	1887	27 753 000 000	1902	1 923 330	1887	4 000	Mch. 1902	9 000	During 1887 it is estimated that 35% of the total rainfall on the catchment area was discharged.
Ovens..........	Waugaratta.	82 948 000 000	1894	6 118 000 000	1902	658 000	1894	....	......	3 000	During 1902 it is estimated that only 5% of the total rainfall on the catchment area was discharged.
Mitta Mitta....	Tallaugatta.	87 987 000 000	1894	12 581 000 000	1902	922 100	1894	4 100	Jan. 1903	2 400	The run-off during 1902 was 10% of the total rainfall. Gaugings from 1886.
Kiewa	Kiewa	29 506 000 000	1894	7 021 000 000	1902	159 000	1889	200	Feb. 1900	700	During 1902, 23% of the rainfall on the catchment area passed the gauging station. Gaugings from 1885.

Mr. Bellamy. The tidal range at the mouth of the river and at Brisbane is between 3 and 8 feet.

The valley of the Brisbane River is the scene of recurring floods, and the highest flood on record at Brisbane occurred on February 5th, 1893. The rainfall recorded for 8 days previous to that date at meteorological stations within the water-shed is as follows:

Cressbrook	20.97 in.	
Crohamhurst	83.43 "	
Esk	18.60 "	
Fassifern	4.53 "	
Ipswich	10.49 "	
Laidley	10.81 "	
Nanango	6.14 "	
Woodford	38.87 "	(gauge overflowed)
Brisbane	19.42 "	

Unfortunately, these records are insufficient to give any reliable data as to the true average fall over the whole area; they are given because they are correct. The cross-section at the railway crossing by Indooroopilly carried the whole of the flood-water. The estimated surface velocity of the current on February 5th was 10 miles per hour. The discharge in the 24-hour period of the flood, when at its maximum height, may be taken at 34 500 000 000 gal.

The Fitzroy River drains a catchment area of about 58 000 sq. miles, the greater portion of which is very flat; and of this area no less than 54 900 sq. miles are above Rockhampton, the capital of Central Queensland. The extreme length of the river, including all bends, measured from the source of the Dawson River Branch to its outlet in Keppel Bay, is 520 miles. The length within tidal influence, extending up to Alligator Creek, about 29 miles above Rockhampton, is only 62 miles. The greatest flood on record occurred in February, 1896, and the estimated maximum discharge of the river for a 24-hour period was 397 226 000 000 gal. The lowest flow ever recorded was gauged by the writer in May, 1902, when the small quantity of 46 000 000 gal. was discharged in 24 hours. The physical conditions of this river are entirely different from those previously referred to, chiefly on account of the water-shed being so very flat.*

In conclusion, the writer desires to state that he considers Mr. Fuller's paper to be the best and most instructive contribution yet published on the subject.

Mr. Kuichling. E. Kuichling, M. Am. Soc. C. E. (by letter)—The author is entitled to unstinted credit for having performed a vast amount of useful work in preparing his extensive compilation and ingenious analysis

* "On the Rainfall of Central Queensland and Floods in the Fitzroy River," by Herbert E. Bellamy, *Minutes of Proceedings*, Inst. C. E., Vol. CLXIII, p. 295.

of flood records of American rivers. The subject is, moreover, a timely one, in view of the extraordinary floods which have occurred this year in Ohio and New York, last year in Wisconsin, and three years ago in Europe. From his studies of the data submitted, he reaches the conclusion that a general formula for computing the probable maximum flood discharge from catchment areas, must be provided with a factor, or coefficient, C, the magnitude of which depends on the peculiarities of each water-shed, and is adapted thereto by considering all previous flood flows therefrom; and, furthermore, that it must have another factor to express the ratio of the probable future maximum discharge to past smaller maxima, which factor is $(1 + 0.8 \log. T)$, wherein T denotes the number of years in the period between the recurrence of floods of approximately the same magnitude. The general formula proposed by the author for the greatest average rate of flow during 24 hours, in cubic feet per second, is $Q = C\ A^{0.8}\ (1 + 0.8 \log. T)$, in which A is the area of the catchment basin, in square miles. Mr. Kuichling.

The values of the variable factor, C, for the rivers of the several geographical districts of the United States, adopted by the U. S. Geological Survey, are given as computed by the author in Tables 12 to 26, inclusive. Two sets of such factors are given, one referring to the average yearly flood discharge in a series of years, T, of observation, and the other to the largest observed discharge during such period. For the sake of clearness, they should be designated, C_1 and C_2, their values being expressed by $C_1 = \frac{Q\,(\text{Ave.})}{A^{0.8}}$ and $C_2 = \frac{Q'}{A^{0.8}\,(1 + 0.8 \log. T)}$, in Columns 8 and 7, respectively, of those tables. It seems to be the author's purpose to use the value C_1 in his aforesaid general formula for Q, as he places $Q = Q$ (Ave.) $(1 + 0.8 \log. T)$, thus giving $Q = C_1\ A^{0.8}\ (1 + 0.8 \log. T)$. The use of the formula may be illustrated by the following example relating to the Susquehanna River at Binghamton, N. Y., in Table 14, where $A = 2\,400$, $T = 10$, Q (Ave.) $= 39\,100$, $C_1 = 78$, and $C_2 = 70$, corresponding to $Q' = 63\,000$ cu. ft. per sec., which is the largest flow observed in 10 years. If it be desired to compute the probable maximum discharge, Q, that will occur in a period of $T = 100$ years, at the same place, the formula will become: $Q = Q$ (Ave.) $(1 + 0.8 \log. T) = 39\,100 \times 2.6 = 101\,660$ cu. ft. per sec.; and in a period of $T = 1\,000$ years, it will be $Q = 39\,100 \times 3.4 = 132\,940$. The coefficient, C_2, should not be used, as it relates only to the particular values, Q' and $T = 10$.

An examination of Tables 12 to 26, inclusive, shows wide differences in the values of C_1 for apparently similar drainage areas. Thus, in Table 14, we have $C_1 = 50$ for the Passaic River, with $A = 823$ and $T = 34$; while for the Raritan River, with $A = 800$ and $T = 6$, the value of C_1 is 93. Similarly, in the same table, we find for the East and West Branches of the Delaware River, at Hancock, N. Y.,

Mr. Kuichling. $C_1 = 140$ and 105, respectively, for $A = 920$ and 680, and $T = 9$ in both cases. Again, in Table 13, we find $C_1 = 58$ and 49 for the Hudson River with respectively $A = 2\,800$ and $4\,500$, and $T = 13$ and 40; while for the Mohawk River, with $A = 3\,440$ and $T = 12$, we have $C_1 = 75$; also, for the neighboring water-sheds of West and East Canada Creeks, with $A = 364$ and 256, and $T = 9$ and 12, we find $C_1 = 116$ and 71, respectively. For nearly equal areas in the basins of the Connecticut, Mohawk, and Delaware Rivers, namely, $A = 3\,305$, $3\,440$, and $3\,250$, with $T = 11$, 12, and 8, we have $C_1 = 49$, 75, and 97, respectively; and similarly with many other catchment areas. The values of C_1 also vary at different points in the same river basin, sometimes increasing with A, sometimes being nearly constant, and sometimes decreasing.

The factor, C_1, appears to depend primarily on the depth and extent of the precipitation causing a flood, the season of the year, and the total drainage area at the point of observation; and, secondarily, on the nature of the surface soil of the water-shed, whether absorptive or impermeable, the slopes of the surface and lines of drainage, the shape of the basin and its component areas, the extent and character of the vegetation thereon, the duration of the excessive rainfall and melting of previously fallen snow, and the extent to which a portion of the run-off is impounded in natural and artificial reservoirs, including the temporary inundation of broad flats in the valley above the point of observation. The latter is an important feature, and in considering the probable future maximum flow from such catchment areas, it will be expedient to assume that improvements will be made, whereby inundations will be reduced. The factor is also affected by the formation and bursting of ice jams in northern streams, and the formation of barriers of sunken logs, silt, and gravel, which may cause a large storage temporarily until scoured away by a strong freshet. It is thus evident that numerous features must be taken into account in estimating the probable maximum flow from a large area.

In regard to the rainfall, it can be said that heavy precipitations covering great areas of country during a few days, occur at more or less regular intervals of years in all the States east of the Mississippi River and on the Pacific Coast. The points where the rainfall is observed, however, are generally so far apart that it is very difficult to estimate the actual volume and distribution of the water on a large territory. In mountainous regions, intense precipitations often occur in localities not provided with rain-gauges, and the fact that unusual downpours have taken place on areas of many square miles, is attested by the resulting freshets, the magnitude of which is not warranted by the scanty available records of rainfall at other places. It happens, therefore, that the rainfall on mountainous and hilly

Mr. Kuichling.

catchment basins is frequently underestimated, as shown by the case of the water-shed of West Canada Creek, N. Y., where in one year the aggregate run-off was much more than the estimated precipitation.

In view of the limited periods of flood observation on most American rivers, and the recurrence of heavy rainfalls at longer intervals of time, it becomes questionable whether the use of different values of C_1 for similar water-sheds in the same region is proper. The same combination of conditions that produced a great flood in one year in a particular basin, is likely to occur in another year in the neighboring basin, and hence it seems safer to use the largest observed value of C_1 for all the streams of a given region when it is known that the area, topography, and character of soil are substantially alike. The variation in the value of C_1 for larger values of A of similar water-sheds of a region, can probably also be deduced from the data, whereby C_1 will be expressed as a function of A; and, as a result we will have a formula like $Q = B\ A^n\ (1 + 0.8 \log. T)$ for all similar catchment basins in a particular region. By this means regional peculiarities would be recognized by variations in the value of the coefficient, B, and perhaps also of the exponent, n. The advantage of such a formula lies in its applicability to a wide range in the value of A.

A question also arises as to the value of T to be used when computing the future maximum flood discharge. The tables contain no reference to the rainfalls that produced the floods listed, nor to the dates of their occurrence, and hence it is impracticable to determine from the data submitted whether a probable maximum flood did not occur during the period of observation. It may also be that the largest observed flood was nearly equal to the future maximum, in which event the factor $(1 + 0.8 \log. T)$ would be correspondingly smaller than 2.5 or 3.0, when T is taken at from 75 to 320 years. Much depends, therefore, on the actual conditions which produced the observed floods, and on this subject no information is given in the paper. The floods of some of the rivers in Ohio, in 1913, were unprecedented in magnitude, and a statement that they might become twice as large in the future would surely have to be accompanied with the most convincing proofs in order to be accepted; and the same can also be said of all other large floods elsewhere.

In regard to the intervals between the occurrence of extraordinary floods, few data are available for American rivers. Table 12 shows that two great floods of nearly equal magnitude occurred in the Connecticut River, at Hartford, Conn., in a period of 104 years; two in the Merrimac River, at Lawrence, Mass., in 56 years; and two in the Androscoggin River, at Rumford Falls, Me., in 40 years. Table 13 shows that one great flood was observed in the Hudson River, at Mechanicsville, N. Y., in 40 years; Table 14, that two great floods

Mr. Kuichling.

were observed in the Passaic River, at Dundee Dam, N. J., in 34 years; Table 17, that two great floods occurred in the Genesee River, at Rochester, N. Y., in 128 years; Table 16, that two great floods of the Ohio River, at Wheeling, W. Va., occurred in 50 years; and Table 20, that one large flood of the Kansas River, at Lecompton, Kans., occurred in 60 years, all other periods of observation being less than 30 years. The average of the foregoing enumeration is one great flood at intervals of 37 years, or a total of 14 in 512 years.

For foreign rivers, a few data as to recurrences of great floods were recently published in official investigations of floods of the Seine, at Paris, and the Danube, at Vienna.* In the Seine at Paris, the observations extend over a period of 400 years, the highest flood having occurred on March 1st, 1658, and the next almost equally high one on January 28th, 1910; the third in order of magnitude, and but slightly lower than the second, was on December 26th, 1740, and between this date and January 7th, 1883, eight other floods of somewhat lower height are recorded. We thus have for the Seine a record of 11 great floods in 255 years, or on the average one unusual flood in 23 years. The discharge of the river at Paris, on January 28th, 1910, was estimated at 83 500 cu. ft. per sec. from a water-shed of about 16 860 sq. miles.

At Vienna the drainage area of the Danube is about 39 200 sq. miles, and from well-attested flood marks, the highest flood occurred in 1501. No reliable data for computing the discharge at that time are available, but, as nearly as can be determined from observations of the river channel during the past 50 years, the maximum flow was then about 503 200 cu. ft. per sec. Numerous smaller floods have occurred since, with discharges reaching 370 800 cu. ft. per sec. in September, 1899; but from a careful study of all existing data relating to the precipitation on the drainage area, the engineer who reported on the subject in 1910 concluded that a recurrence of the great flood of 1501 was highly probable, and might take place in any year of excessive rainfall.

Other records for European rivers might also be cited, to show that great floods have occurred in shorter intervals than 100 years; but it is believed by the writer that enough has been adduced to show that the proper value of T to be used in making estimates of future flood flows of American rivers, deserves further explanation by the author.

Generous reference has been made in the paper to the writer's extensive study of the subject, as published in the State Engineer's "Report on the Barge Canal of the State of New York", Albany, 1901. In this publication the drainage areas and maximum flood discharges, in cubic feet per second per square mile, of 232 American and 364

* Abstracts thereof are given in *Engineering News*, 1910, I, p. 327, and *Zeitschrift des Oesterr. Ingenieur- u. Architekten Vereines*, 1910, pp. 147 and 457, respectively.

foreign river basins were submitted, together with 18 different formulas, reprinted in Table 29, that had been devised up to 1900 by various engineers for estimating the probable maximum flow of a stream. Although these data are very useful, they are too long for reproduction here, especially as many of them are contained in the author's tables, and therefore the writer will append only the additional data on large flood discharges that he has collected since the year 1900. Mr. Kuichling.

An examination of the figures soon shows wide differences in the rates of maximum discharge for water-sheds of the same magnitude in different parts of the world, and confirms the view of the author that it is necessary to take into account the topographical, geological, and meteorological characteristics of a drainage area before estimating the probable maximum run-off therefrom. This opinion has long been held by hydrologists, and hence most of the various formulas for flood discharge are adapted only to particular localities. Doubtless the most important factors are the intensity, duration, and distribution of the rainfall on the water-shed, but owing to lack of sufficient data on this subject in almost every country and State, it becomes extremely difficult to establish even an approximately correct relation between them. For rains of comparatively long duration, the character of the surface soil seems to be of minor importance, as the ground usually becomes saturated in a few hours and absorption diminishes in large degree; whereas, for short heavy downpours, the condition of the soil and the vegetation thereon is of great influence on the run-off, especially as the area covered by such precipitation is then relatively small. The largest rate of run-off that the writer has found recorded is 3 200 cu. ft. per sec. per sq. mile, on July 14th, 1897, from an area of only 0.25 sq. mile of irregular rocky surface on Beacon Mountain, near Fishkill, N. Y.

Reference may also be made to the following formula* of R. Iszkowski, Chief Engineer of the Austrian Ministry of Public Works. This is called an "induction formula for estimating the normal and flood discharges, based on the characteristics of the water-shed," and involves four direct factors, viz.: the area (M) of the water-shed; the mean yearly depth (R) of rainfall thereon; two variable coefficients, one (C_1) depending on the topography or general slope of the territory, and the other (C_2) on the character of the surface soil, according as it is strongly absorptive, slightly permeable, or impervious; and lastly, a special factor (m) which varies inversely with the area of the water-shed. In its original form, for the metrical system, this formula is $Q_{max.} = (0.022\ C_1 + m C_2)\ R\ M$, where $Q_{max.}$ is the probable maximum flood discharge, in cubic meters per second, (R) is the mean annual depth of rainfall, in meters, and (M) is the drainage

* Published in *Wochenschrift des Oester. Ingenieur und Architekten Vereines*, Vol. 9, 1884, pp. 25, 33, and 146.

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area, in square kilometers. For this system of measures, the value of the coefficient (C_1) ranges from 0.20 for very flat, sandy, or swampy areas, to 0.65 for high mountainous areas; the value of (C_2) ranges from 0.035 for very permeable land covered with vegetation to 0.70 for impervious rocky or frozen land, without active vegetation, and covered with snow which will increase the run-off by melting; and the value of (m) ranges from 7.88 for $M = 10$ sq. km. to 0.65 for $M = 100\,000$ sq. km., as set forth in a table from which the writer has deduced the approximate relation: $m = \frac{0.59\,(11\,050 + M)}{818 + M}$. For average conditions, such as correspond to a hilly territory with slightly permeable soil and sparse vegetation, the values of the said coefficients are $C_1 = 0.385$ and $C_2 = 0.40$. By substituting these particular values in the formula and then reducing to the customary measures of discharge (q) in cubic feet per second per square mile, area (M) in square miles, and the mean annual depth of rainfall (R) in inches, we will have:

$$q_{max} = \frac{0.568\,.\,R\,(4\,129.5 + M)}{315.8 + M} \qquad \text{..............} \quad (1)$$

in cubic feet per second per square mile, for the aforesaid average conditions. If we assume $R = 36$ in., this expression will give $q_{max.} = 260$, 208, 80, and 28 for $M = 10$, 100, 1 000, and 10 000, respectively. For mountainous territory with rocky or frozen soil, we will have $C_1 = 0.50$ and $C_2 = 0.60$ in the original formula, whence by reduction:

$$q_{max.} = \frac{0.848\,.\,R\,(4\,147.4 + M)}{315.8 + M} \qquad \text{..............} \quad (2)$$

in cubic feet per second per square mile. For the same values of (R) and (M) as before, this second equation gives $q_{max} = 390$, 312, 119, and 42, or 50% more than by Equation (1). Similar expressions might also be deduced for other values of (C_1) and (C_2), but they will be omitted here as it is doubtful whether the formula can be applied generally without modification. In the writer's opinion, the formula gives values of (q) that are too low for small drainage areas and too high for large ones. The method of development, however, is ingenious and worthy of closer investigation.

On page 1062* of the paper a formula is given that was devised by the writer in 1900 for the probable maximum flood discharge from mountainous and hilly water-sheds of not more than 5 000 sq. miles in the Middle and New England States. Since that time many other data have become available, so that this formula should now be modified. Further studies of the subject have led the writer to propose another simple formula which applies to river basins in the Southern

* *Proceedings*, Am. Soc. C. E., May, 1913.

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TABLE 37.—UNUSUAL FLOOD DISCHARGES, SUPPLEMENTARY TO THE DATA COMPILED BY THE WRITER, AND PUBLISHED IN THE REPORT ON THE PROPOSED BARGE CANAL FOR THE STATE OF NEW YORK, ALBANY, 1901, pp. 845-865. ARRANGED ACCORDING TO MAGNITUDE OF DRAINAGE AREA.

Stream and locality.	Drainage area, in square miles.	Maximum discharge, in cubic feet per second per square mile.	Date of flood.	Number of years observed.	Authority.*
I. AMERICAN STREAMS.					
Mississippi River, at St. Louis, Mo.	702 380	1.28	June, 1883	6 (1880–85)	(30)
Missouri River, at St. Charles, Mo.	530 810	1.13	June, 1883	6 (1880–85)	(30)
Missouri River, at Sioux City, Ia.	323 462	1.64	Apr., 1881	6 (1880–85)	(30)
Colorado River, at Yuma, Ariz.	225 000	0.67	June, 1909	11 (1902–12)	(6)
Ohio River, at Paducah, Ky.	205 750	7.00	Feb., 1884	6 (1880–85)	(30)
Mississippi River, at Grafton, Ill.	171 570	2.10	June, 1883	6 (1880–85)	(30)
Mississippi River, at Clayton, Ia.	79 040	2.66	June, 1880	6 (1880–85)	(30)
Kansas River, at Lawrence, Kans.	59 841	3.8	May 31, 1903	25 (1881–05)	(1)
Platte River, near Columbus, Neb.	56 900	0.83	May 15, 1905	12 (1895–06)	(14)
Mississippi River, at Prescott, Wis.	44 070	2.50	Apr., 1881	6 (1880–85)	(30)
Colorado River, at Austin, Tex.	37 000	3.33	Apr. 7, 1900	9 (1896–04)	(1)
Mississippi River, at St. Paul, Minn.	36 085	3.32	Apr. 29, 1881	46 (1867–12)	(1) and (25)
Mississippi River, at St. Paul, Minn.	35 700	2.26	Apr., 1897	46 (1867–12)	(1) and (25)
Red River, at Grand Forks, N. D.	25 000	1.70	Apr., 1897	31 (1882–12)	(25)
North Platte River, at Camp Clarke, Neb.	24 800	0.95	June 26, 1899	11 (1896–06)	(14)
Susquehanna River, at Harrisburg, Pa.	24 030	30.6	June, 1889	41 (1865–05)	(1)
Susquehanna River, at Harrisburg, Pa.	24 030	30.6	Mar., 1865	41 (1865–05)	(1)
Ohio River, at Wheeling, W. Va.	23 800	20.8	Feb. 7, 1884	22 (1884–05)	(1)
Ohio River, at Wheeling, W. Va.	23 800	19.00	Mar., 1907	28 (1884–11)	(2)
Republican River, at Bostwick, Neb.	22 300	1.10	July 4, 1905	11 (1896–06)	(14)
Tennessee River, at Chattanooga, Tenn.	21 382	34.37	Mar. 11, 1867	38 (1867–04)	(1)
Ohio River, at Pittsburgh, Pa.	19 100	22.98	Mar. 15, 1907	30 (1884–13)	(33)
Mississippi River, at Anoka, Minn.	17 100	2.87	Apr., 1897	9 (1897 and 1905–12)	(25)
Illinois River, at Peoria, Ill.	15 700	3.66	Mar. 28, 1904	16 (1890–05)	(1)
Alabama River, at Selma, Ala.	15 400	9.5	Jan. 19, 1892	14 (1891–04)	(1)

* A list of these authorities is given at the end of this table.

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TABLE 37.—(*Continued.*)

Stream and locality.	Drainage area, in square miles.	Maximum discharge, in cubic feet per second per square mile.	Date of flood.	Number of years observed.	Authority.
Minnesota River, near Mankato, Minn.....	14 600	3.00	June, 1908	10 (1903–12)	(25)
Loup River, at Columbus, Neb.	13 540	5.17	June 6, 1896	12 (1895–06)	(1)
Sacramento River, at Red Bluff, Cal..	10 400	24.42	Feb., 1909	11 (1902–12)	(8)
Sacramento River, at Jelly's Ferry, Cal.....	10 200	12.05	Mar., 1900	8 (1895–02)	(8)
Connecticut River, at Hartford, Conn.......	10 234	20.0	May, 1854	105 (1801–1905)	(1)
Susquehanna River, at Wilkes-Barre, Pa.....	9 810	22.2	May 2, 1902	7 (1899–05)	(1)
Potomac River, at Point of Rocks, Md.	9 654	48.9	June 2, 1889	18 (1889–06)	(1) and (17)
Potomac River, at Point of Rocks, Md.	9 654	22.66	Mar., 1902	18 (1889–06)	(1) and (17)
Blue River, near Manhattan, Kans..	9 490	7.25	May, 1903	9 (1895–03)	(19)
Allegheny River, at Kittanning, Pa........	9 010	26.66	Mar. 20, 1905	8 (1904–11)	(22)
Grand River, at Palisade, Colo........	8 546	4.88	June 5, 1905	4 (1902–05)	(1)
Smoky Hill River, at Ellsworth, Kans......	7 980	2.63	July, 1895	9 (1895–03)	(19)
Gunnison River, at Whitewater, Colo.....	7 863	3.67	June 5, 1905	4 (1902–05)	(1)
Penobscot River, at Bangor, Me...........	7 700	14.94	Apr. 10, 1901	35 (1875–09)	(10)
Savannah River, at Augusta, Ga..........	7 500	40.00	Sept. 11, 1888	66 (1840–05)	(1)
Delaware River, at Lambertville, N. J..	6 855	37.14	Jan. 8, 1841	120 (1786–1905)	(1)
Delaware River, at Lambertville, N. J..	6 855	32.62	June 8, 1862	120 (1786–1905)	(1)
Chippewa River, at Eau Claire, Wis.......	6 740	9.00	June 8, 1905	4 (1902–05)	(1)
Cedar River, at Cedar Rapids, Ia......	6 320	3.75	Mar., 1910	3 (1909–11)	(4)
Rock River, below Rockton, Ill......	6 290	4.31	Mar., 1904	7 (1903–09)	(4)
Fox River, at Rapide Croche Dam, Wis....................	6 200	2.49	June, 1895	10 (1895–04)	(18)
Niobrara River, near Valentine, Neb.....	6 070	1.15	July 18, 1903	7 (1901–07)	(14)
St. Croix River, near St. Croix Falls, Minn................	5 930	5.65	May, 1912	7 (1902–05, 1910–12)	(25)
Monongahela River, at Lock No. 4, Pa.......	5 430	38.12	July 11, 1888	20 (1886–05)	(1)
Red Lake River, at Crookston, Minn.....	5 320	2.67	Apr., 1906	12 (1901–12)	(25)
Flint River, at Albany, Ga..........	5 000	7.79	Feb 17, 1905	4 (1902–05)	(16)
Grand River, at Grand Rapids, Mich.	4 900	8.04	Mar. 27, 1904	Indefinite	(2)
Merrimac River, at Lawrence, Mass......	4 553	18.04	Mar., 1896	59 (1846–04)	(15)
Mississippi River, above Sandy River, Minn.	4 510	2.12	Sept., 1900	18 (1895–12)	(25)

TABLE 37.—(*Continued.*)

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Stream and locality.	Drainage area, in square miles.	Maximum discharge, in cubic feet per second per square mile.	Date of flood.	Number of years observed.	Authority.
Hudson River, at Mechanicville, N. Y...	4 500	26.67	Mar. 28, 1913	26 (1888–13)	(37)
Kennebec River, at Waterville, Me.......	4 270	35.36	Dec. 16, 1901	14 (1893–06)	(15)
Oconee River, at Dublin, Ga............	4 182	8.35	Feb. 12, 1903	8 (1898–05)	(16)
Pit River, near Bieber, Cal.........	4 040	6.81	Mar., 1907	5 (1904–08)	(8)
Coosa River, at Rome, Ga.............	4 006	16.02	Dec. 31, 1901	7 (1897–03)	(16)
Neosho River, at Iola, Kans............	3 670	20.33	July 10, 1904	9 (1896–04)	(2)
Feather River, at Oroville, Cal..........	3 640	51.37	Mar., 1907	11 (1902–12)	(8)
Crow Wing River, near mouth, Minn.....	3 580	2.85	Apr., 1897	3 (1882, 1884 and 1897)	(25)
Mohawk River, at Cohoes, N. Y.........	3 472	28.50	Mar. 27, 1913	26 (1888–13)	(37)
Chattahoochee River, at West Point, Ga.......	3 300	26.86	Dec. 30, 1901	10 (1896–05)	(16)
Wabash River, at Logansport, Ind......	3 163	17.99	Mar. 27, 1904	21 (1885–05)	(2)
Klamath River, at Keno, Ore	3 150	2.68	June, 1904	7 (1904–10)	(6)
Link River, at Klamath Falls, Ore...	3 110	2.90	Mar., 1904	7 (1904–10)	(6)
Verdigris River, at Liberty, Kans.........	3 067	16.45	July 8, 1904	10 (1895–04)	(2)
Shenandoah River, at Millville, W. Va.......	2 995	46.65	Oct., 1896	12 (1895–06)	(17)
Catawba River, near Rock Hill, S. C.....	2 987	50.50	May 23, 1901	9 (1895–03)	(34)
Hudson River, at Glens Falls, N. Y	2 760	25.36	Mar. 28, 1913	15 (1899–13)	(37)
Saline River, at Beverly, Kans.........	2 730	5.86	June, 1896	9 (1895–03)	(19)
New River, at Radford, Va........	2 725	63.78 63.37	Oct., 1900 May, 1901	13 (1898–10)	(21*a*)
Savannah River, near Calhoun Falls, S. C..................	2 712	27.76	Feb. 14, 1900	6 (1896–1900 & 1903)	(16)
Kennebec River, bet. Forks & Waterville.	2 700	48.56	Dec. 16, 1901	14 (1893–06)	(15)
Wisconsin River, near Merrill, Wis........	2 630	8.02	Sept. 16, 1903	4 (1902–05)	(18)
Sangamon River, at Riverton, Ill..........	2 560	7.50	Oct., 1911	4 (1908–11)	(4)
Elkhorn River, near Norfolk, Neb.......	2 470	3.24	May 30, 1903	8 (1896–03)	(11)
Chemung River, at Chemung, N. Y......	2 440	21.52	Mar. 28, 1913	11 (1903–13)	(37)
Ocmulgee River, at Macon, Ga.............	2 425	20.97	Mar. 1, 1902	13 (1893–05)	(16)
Menominee River, near Iron Mountain, Mich....................	2 415	4.87	May, 1904	4 (1902–05)	(18)
Genesee River, at Rochester, N. Y	2 365	17.42	Mar. 28, 1913	22 (1892–13)	(37)
Kern River, at Bakersfield, Cal......	2 345	4.05	June, 1906	19 (1893–11)	(7)

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TABLE 37.—(*Continued.*)

Stream and locality.	Drainage area, in square miles.	Maximum discharge, in cubic feet per second per square mile.	Date of flood.	Number of years observed.	Authority.
Androscoggin River, at Rumford Falls, Me....	2 320	23.81	Apr. 22, 1895	12 (1893–04)	(15)
N. Fork Feather River, at Big Bend, Cal.........	1 940	56.34	Mar. 19, 1907	6 (1905–10)	(8)
American River, at Fair Oaks, Cal........	1 910	55.00	Mar., 1907	9 (1904–12)	(8)
W. Branch Penobscot River, at Millinocket, Me.	1 880	12.90	Apr. 1, 1903	9 (1901–09)	(10)
Kings River, near Sanger, Cal	1 740	25.25	Jan., 1901	18 (1895–12)	(7)
Kiskiminetas River, at Avonmore, Pa........	1 720	39.10	Mar., 1908	5 (1907–11)	(22)
Allegheny River, at Red House, N. Y......	1 640	25.00	Mar. 2, 1910	8 (1904–11)	(22)
San Joaquin River, at Hamptonville, Cal..	1 637	36.53	Jan., 1881	16 (1879–82) (1895–01) and (1907–12)	(7)
Oostanaula River, at Resaca, Ga..........	1 614	14.88	Mar. 17, 1899	7 (1896–1901 and 1905)	(16)
Kennebec River, at Forks, Me.	1 570	12.67	Dec. 16, 1901	6 (1901–06)	(15)
S. Fork Shenandoah River, near Front Royal, Va....	1 570	48.92	Mar., 1902	8 (1899–06)	(17)
Chattahoochee River, at Oakdale, Ga..........	1 560	31.28	Dec. 30, 1901	10 (1895–04)	(16)
Catawba River, at Catawba, N. C........	1 535	61.89	May 23, 1901	10 (1896–05)	(34)
Tuolumne River, at Lagrange, Cal........	1 500	35.07	Jan., 1911	18 (1895–12)	(7)
S. Branch Potomac River, near Springfield, W. Va................	1 440	17.81	Mar., 1906	8 (1894–5) (1899–01) (1904–06)	(17)
Genesee River, at Mt. Morris, N. Y......	1 410	12.52	Mar. 27, 1913	22 (1892–13)	(37)
Cheat River, at Morgantown, W. Va..	1 380	30.29	Jan., 1911	13 (1899–11)	(22)
Tygart Valley River, at Fetterman, W. Va.....	1 327	26.36	Jan., 1911	5 (1907–11)	(22)
Youghiogheny River, at Connellsville, Pa......	1 320	27.50	June, 1910	4 (1908–11)	(22)
Chagres River, at Gatun, Panama.......	1 320	93.9	Dec. 28, 1909	20 (1894–13)	(32)
Mohawk River, at Little Falls, N. Y.....	1 306	26.65	Mar. 27, 1913	16 (1898–13)	(37)
Cache Creek, at Yolo, Cal..............	1 230	16.34	Feb., 1909	10 (1903–12)	(8)
Yuba River, near Smartsville, Cal....	1 220	90.91	Jan., 1909	10 (1903–12)	(8)
Raquette River, at Massena Springs, N.Y.	1 170	9.40	May, 1909	8 (1904–11)	(5)
E. Branch Penobscot River, at Grindstone, Me.	1 100	23.36	Sept. 29, 1909	8 (1902–09)	(10)
Merced River, near Merced Falls, Cal..	1 090	34.13	Jan., 1911	11 (1901–11)	(7)
French Creek, at Carlton, Pa...........	1 070	22.93	Mar., 1910	4 (1908–11)	(22)
Sacandaga River, at Hadley, N. Y..........	1 060	27.36	Mar. 28, 1913	7 (1907–13)	(37)

TABLE 37.—(*Continued.*)

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Stream and locality.	Drainage area, in square miles.	Maximum discharge, in cubic feet per second per square mile.	Date of flood.	Number of years observed.	Authority.
Scioto River, at Columbus, O.	1 047	80.82	Mar. 25, 1913	Indefinite.	(39)
N. Fork Shenandoah River, near Riverton, Va.	1 037	20.86	Apr., 1901	8 (1899–06)	(17)
Flint River, near Woodbury, Ga.	988	30.62	Feb. 28, 1902	6 (1900–05)	(16)
Truckee River, near State line, Cal.	955	16.02	Mar., 1907	14 (1899–12)	(6)
Stanislaus River, at Knight's Ferry, Cal.	935	61.18	Mar., 1907	10 (1903–12)	(7)
Clarion River, at Clarion, Pa.	910	43.20	Mar., 1905	27 (1885–11)	(22)
Schoharie Creek, at Fort Hunter, N. Y.	909.3	44.56	Mar. 27, 1913	16 (1898–13)	(37)
Schoharie Creek, at Fort Hunter, N. Y.	900.0	55.11	Mar. 21, 1901	16 (1898–13)	(37)
Youghiogheny River, below Confluence, Pa.	874	52.63	Aug. 21, 1888	32 (1874–05)	(1)
Dead River, near The Forks, Me.	870	20.74	May, 1904	5 (1902–06)	(15)
Minnesota River, above Whetstone River, Minn.	846	0.11	Mar., 1903	6 (1899–04)	(25)
Kettle River, near Sandstone, Minn.	825	7.15	May, 1912	4 (1909–12)	(25)
Passaic River, at Dundee, N. J.	823	38.16	Oct. 10, 1903	95 (1810–05)	(24)
Raritan River, at Bound Brook, N. J.	806	64.52	Sept. 24, 1882	96 (1810–05)	(1)
Putah Creek, at Winters, Cal.	805	37.27	Mar., 1907	8 (1905–12)	(8)
North River, at Port Republic, Va.	804	29.69	Sept., 1896	5 (1895–99)	(17)
Hudson River, at North Creek, N. Y.	804	35.08	Mar. 28, 1913	7 (1907–13)	(37)
Chagres River, at Bohio, Panama	779	115.5	Dec. 27, 1909	20 (1894–13)	(32)
Broad River, near Carlton, Ga.	762	38.22	Feb. 28, 1902	9 (1897–05)	(16)
West Fork River, at Enterprise, W. Va.	744	23.67	Jan., 1911	5 (1907–11)	(22)
Big Muddy River, near Cambon, Ill.	735	14.97	May, 1911	4 (1908–11)	(4)
Santa Ynez River, near Lompoc, Cal.	725	28.14	Mar., 1911	5 {(1906–08) (1910–12)}	(6)
Raquette River, at Piercefield, N. Y.	723	8.13	May, 1911	4 (1908–11)	(5)
Little Tennessee River, at Judson, N. C.	675	85.3	Dec., 1901	15 (1896–10)	(21)
Monocacy River, near Frederick, Md.	660	31.00	Mar., 1902	11 (1896–06)	(17)
Mokelumne River, near Clements, Cal.	642	26.01	Jan., 1911	8 (1905–12)	(7)
McCloud River, near Gregory, Cal.	608	68.26	Mar., 1904	7 (1902–08)	(8)
Hoosic River, at Johnsonville, N. Y.	605	38.01	Mar. 28, 1913	11 (1903–13)	(37)
Etowah River, at Canton, Ga.	604	28.30	Dec. 29, 1901	9 (1896–04)	(16)

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TABLE 37.—(*Continued.*)

Stream and locality.	Drainage area, in square miles.	Maximum discharge, in cubic feet per second per square mile.	Date of flood.	Number of years observed.	Authority.
Stony Creek River, near Fruto, Cal..........	601	48.75	Feb., 1909	12 (1901-12)	(8)
Tugaloo River, near Madison, S. C......	593	36.86	July 1, 1905	8 (1898-05)	(16)
Conewango Creek, at Frewsburg, N. Y......	550	20.95	Jan., 1911	2 (1910-11)	(22)
Santa Catarina River, at Monterey, Mex........	544	590.00	Aug. 27, 1909	Indefinite.	(35)
Coosawattee River, at Carters, Ga............	531	31.92	May 21, 1901	10 (1896-05)	(16)
Cosumnes River, at Michigan Bar, Cal....	524	42.75	Jan., 1911	6 (1907-12)	(7)
Truckee River, at Tahoe, Cal..........	519	2.60	July, 1907	14 (1895 and 1900-12)	(6)
Olentangy River, at Columbus, O..........	514	70.00	Mar. 25, 1913	Indefinite.	(39)
N. Fork Feather River, below Prattville, Cal.....	506	19.47	Mar., 1907	6 (1905-10)	(8)
Deerfield River, at Shelburne Falls, Mass.	501	42.51	Apr. 15, 1909	4 (1907-10)	(12)
Cache Creek, at Lower Lake, Cal......	500	8.68	Feb., 1909	12 (1901-12)	(8)
Ausable River, at Ausable Forks, N. Y..	487	45.17	Mar. 27, 1913	....	(37)
Cattaraugus Creek, at Versailles, N. Y.......	467	53.53	Mar. 25, 1913	....	(37)
Tionesta Creek, at Nebraska, Pa..........	451	20.40	Jan., 1911	2 (1910-11)	(22)
Casselman River, at Confluence, Pa........	448	43.89	Mar., 1907	7 (1905-11)	(22)
Battenkill, at Greenwich, N. Y......	444	21.65	Mar. 28, 1913	3 (1911-13)	(37)
Whetstone River, at Bigstone, S. D.......	441	2.95	Apr., 1910	9 (1899-04) (1910-12)	(25)
Apalachee River, near Buckhead, Ga......	440	15.19	Mar. 1, 1902	5 (1901-05)	(16)
Youghiogheny River, at Confluence, Pa........	435	52.07	Mar., 1907	7 (1905-11)	(22)
Chagres River, at Alhajuela, Panama...	427	398.1	Dec. 26, 1909	20 (1894-13)	(32)
S. Fork Sangamon River, at Taylorville, Ill........	427	9.70	Sept., 1911	4 (1908-11)	(4)
Rio Mora, at Weber, N. M..........	422	65.70	Sept. 29, 1904	....	(2)
Mahoning Creek, at Furnace Bridge, Pa...	412	30.51	Feb., 1910	2 (1910-11)	(22)
Hiwassee River, at Murphy, N. C.........	410	54.54	Mar. 19, 1899	9 (1897-05)	(16)
N. Branch Potomac River. at Piedmont, W. Va......	410	32.80	Feb., 1902	8 (1899-06)	(17)
Tygart Valley River, at Belington, W. Va......	403	40.88	July, 1907	5 (1907-11)	(22)
Mohave River, at Victorville, Cal.......	400	33.53	Mar., 1903	7 (1899-05)	(6)
Pacolet River, at Spartansburg, S. C....	400	88.90	June 6, 1903	....	(19)
Calaveras River, at Jenny Lind, Cal......	395	176.20	Jan., 1911	6 (1907-12)	(7)
Middle Oconee River, near Athens, Ga.........	395	49.52	Feb. 28, 1902	2 (1901-02)	(16)

TABLE 37.—(*Continued.*)

Mr. Kuichling.

Stream and locality.	Drainage area, in square miles.	Maximum discharge, in cubic feet per second per square mile.	Date of flood.	Number of years observed.	Authority.
Black Lick Creek, at Black Lick, Pa........	386	50.82	Mar., 1905	8 (1904–11)	(22)
E. Fork Carson River, near Gardnerville, Nev.	381	8.69	Feb., 1904	10 { 1890–91 / 1900–10 }	(6)
Pompton River, at Two Bridges, N. J.....	380	61.60	Oct. 10, 1903	....	(1)
Rondout Creek, at Rosendale, N. Y.......	380	51.34	Apr. 26, 1910	12 (1901–12)	(9)
Esopus Creek, at Mt. Marion, N. Y.	378	65.34	Apr. 26, 1910	6 (1907–12)	(9)
W. Canada Creek, at Trenton Falls, N. Y ..	376	96.54	Dec. 15, 1901	16 (1898–13)	(37)
W. Canada Creek, at Trenton Falls, N. Y ..	376	69.15	Mar. 28, 1913	16 (1898–13)	(37)
W. Canada Creek, at Hinckley, N. Y........	372	104.57	Apr. 21, 1869	45 (1869–13)	(37)
Carrabassett River, at N. Anson, Me..........	340	40.21	May, 1904	5 (1902–06)	(15)
Silver Creek, near Lebanon, Ill........	335	15.64	May, 1908	4 (1908–11)	(4)
San Luis Rey River, near Pala, Cal.	318	40.88	Mar., 1906	8 (1903–11)	(6)
Oil Creek, at Rouseville, Pa........	302	27.71	Mar., 1910	2 (1910–11)	(22)
Antietam Creek, near Sharpsburg, Md....	295	23.17	Feb., 1902	9 (1897–05)	(17)
Youghiogheny River, at Friendsville, Md......	294	27.76	Mar., 1904	6 (1899–04)	(22)
Brokenstraw Creek, at Youngsville, Pa......	290	24.50	Mar., 1910	2 (1910–11)	(22)
Piscataquis River, at Foxcroft, Me.........	286	77.62	Sept. 29, 1909	8 (1902–09)	(10)
Crooked Creek, at Hileman's Farm, Pa.	279	43.37	Sept., 1911	2 (1910–11)	(22)
Nottely River, at Ranger, N. C..........	272	20.81	Feb. 28, 1902	5 (1901–05)	(16)
Miller Creek, near Lovella, Ore........	270	24.93	Feb., 1907	9 (1904–12)	(6)
Tule River, near Portersville, Cal...	266	20.41	Dec., 1909	12 (1901–12)	(7)
Bear River, at Van Trent, Cal........	263	98.10	Mar., 1907	9 (1904–12)	(8)
Salmon River, at Pulaski, N. Y.	260	41.65	Mar. 27, 1913	16 (1898–1913)	(37)
Cahokia Creek, near Poag, Ill............	259	13.90	Oct., 1911	3 (1909–11)	(4)
East Canada Creek, at Dolgeville, N. Y.......	256	54.30	Mar. 27, 1913	16 (1898–13)	(37)
Susan River, at Susanville, Cal........	256	7.03	Mar., 1903	6 (1900–05)	(6)
South River, at Port Republic, Va....	246	37.40	Sept., 1896	5 (1895–99)	(17)
Cobbosseecontee Stream, at Gardiner, Me..........	240	13.65	Mar., 1903	17 (1890–06)	(15)
Esopus Creek, at Olivebridge, N. Y.....	239	64.39	Apr. 26, 1910	7 (1906–12)	(9)
Toccoa River, near Blueridge, Ga......	231	53.20	Aug. 23, 1901	6 (1898–03)	(16)
Alcovy River, near Covington, Ga.....	228	9.52	Feb. 28, 1902	4 (1901–04)	(16)

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TABLE 37.—(*Continued.*)

Stream and locality.	Drainage area, in square miles.	Maximum discharge, in cubic feet per second per square mile.	Date of flood.	Number of years observed.	Authority.
San Gabriel River, near Azusa, Cal..........	222	56.31	Jan., 1910	19 (1894–12)	(6)
Sapella River, near Los Alamos, N. M..	221	36.67	Sept. 29, 1904	....	(2)
Arroyo Seco, near Soledad, Cal........	215	61.86	Mar., 1911	12 (1901–12)	(6)
N. Branch French Creek, at Kimmeytown, Pa.....	212	43.35	Jan., 1911	2 (1910–11)	(22)
Catskill Creek, at S. Cairo, N. Y.........	210	100.00	Spring, 1901	....	(27)
Santa Ynez River, near Santa Barbara, Cal..................	207	45.65	Jan., 1907	6 (1904–07, 1911–12)	(6)
Fishkill Creek, at Glenham, N. Y.......	198	69.19	Mar. 1, 1902	3 (1901–03)	(21)
Tallulah River, at Tallulah Falls, Ga..	191	40.63	Dec. 29. 1901	4 (1900–01, 1904–05)	(16)
Santa Ana River, near Mentone, Cal.......	182	26.97	Apr., 1903	11 (1902–12)	(6)
E. Branch Fish Creek, at Taberg, N. Y..........	169	65.09	Mar. 27, 1913	16 (1898–13)	(37)
Kinzua Creek, at Dewdrop, Pa..........	162	19.94	Mar., 1910	2 (1910–11)	(22)
Ramapo River, at Pompton, N. J........	160	65.88	Sept. 22, 1882	....	(24)
Rio Mora, below Mora, N. M........	159	139.70	Sept. 29, 1904	....	(2)
Turtle Creek, at East Pittsburgh, Pa...	146	64.21	Mar., 1904	Indefinite.	(26)
Oriskany Creek, at Oriskany, N. Y.......	144	51.0	Dec. 16, 1901	7 (1898–04)	(27)
Devil's Creek, near Viele, Ia............	143	1 300.0	June 10, 1905	....	(1)
Santa Ysabel Creek, near Escondido, Cal.....	128	50.78	Jan., 1909	7 (1906–12)	(6)
Laurel Hill Creek......... at Confluence, Pa.......	126	40.00	Mar., 1907	7 (1905–11)	(22)
Rockaway River, at Boonton, N. J.........	118	48.85	Oct. 10, 1903	....	(24)
Lewistown Reservoir. Outlet, Ohio.............	111	57.66	Mar. 25, 1913	Indefinite.	(38)
Onondaga Creek, at Syracuse. N. Y.......	108	30.00	Mar. 25, 1913	Indefinite.	(37)
E. Branch Fish Creek, at Point Rock, N. Y.....	104.3	80.54	Fall, 1897	Indefinite.	(27)
Little Stony Creek, near Lodoga, Cal........	102	69.22	Feb., 1909	5 (1908–12)	(8)
Wanaque River, at Pompton, N. J........	101	83.61	Oct. 10, 1910	Indefinite.	(24)
Putah Creek, near Guenoc, Cal........	91	198.90	Mar., 1904	3 (1904–06)	(8)
Butte Creek, near Butte Valley, Cal..	73	22.47	Jan., 1909	6 (1905–10)	(8)
Loramie Reservoir Outlet, Ohio....................	72	97.22	Mar. 25, 1913	Indefinite.	(38)
W. Fork Carson River, at Woodfords, Cal.......	70	22.43	May, 1906	12 (1900–11)	(6)
Pequannock River, at Macopin, N. J.........	62	90.84	Oct. 10, 1903	Indefinite.	(20)

TABLE 37.—(*Continued.*)

Mr. Kuichling.

Stream and locality.	Drainage area, in square miles.	Maximum discharge, in cubic feet per second per square mile	Date of flood.	Number of years observed.	Authority.
N. Fork Cottonwood Creek, at Ono, Cal	52	77.70	Feb., 1909	6 (1907–12)	(8)
Kosk Creek, near Henderson, Cal	51.9	44.32	Apr., 1911	2 (1910–11)	(8)
Six Mile Creek, at Ithaca, N. Y	46.0	185.0	June 21, 1905	Indefinite.	(1)
Elkhorn Creek, at Keystone, W. Va	44.0	1 363.0	June 22, 1901	Indefinite.	(34)
Basic Creek, at Freehold, N. Y	41.0	81.22	Spring, 1901	Indefinite.	(27)
Whippany River, at Whippany, N. J	38.0	84.20	Feb. 6, 1896	Indefinite.	(24)
Bear Grass Creek, at Louisville, Ky	27.5	100.0	Feb. 22, 1908	Indefinite.	(40)
Pequonnock River, near Bridgeport, Conn	25.0	157.0	July 29, 1905	Indefinite.	(1)
Pinal Creek, at Globe, Ariz	25.0	560.	Aug. 17, 1904	Indefinite.	(2)
Cane Creek, at Bakersville, N. C	22.0	1 341.	May 20, 1901	Indefinite.	(34)
Willow Creek, near Heppner, Ore	20.0	1 800.	June 14, 1903	Indefinite.	(19)
Goodyear Creek, at Goodyear Bar, Cal	12.2	96.72	Jan. 30, 1911	Indefinite.	(3)
Mill Brook, at Sherburne, N. Y	9.4	241.0	Sept. 4, 1905	Indefinite.	(1)
Camp Branch, at Ensley, Ala	7.43	68.77	June, 1909	2 (1909–10)	(11)
Mill Brook, at Sherburne, N. Y	5.0	262.0	Sept. 4, 1905	Indefinite.	(1)
Reel's Creek, near Deerfield, N. Y	4.42	66.92	June 21, 1903	4 (1901–04)	(28)
Venison Branch, near Mulga, Ala	3.87	53.49	June, 1909	2 (1909–10)	(11)
Estanzuela River, near Monterey, Mex	3.50	825.0	Aug. 28, 1909	Indefinite.	(35)
Starch Factory Creek, near New Hartford, N. Y.	3.40	151.6	July 11, 1905	3 (1903–05)	(29)
Rio Grande, near Culebra, Panama	2.36	161.0	May 25, 1911	Indefinite.	(32)
Cherryvale Creek, at Cherryvale, Kans	2.00	930.0	....	Indefinite.	(31)
Budlong Creek, near Utica, N. Y	1.13	120.40	Mar. 25, 1904	Indefinite.	(2)
Beacon Brook, near Fishkill, N. Y	0.25	3 200.00	July 14, 1897	18 (1896–13)	(27)
II. EUROPEAN STREAMS.					
Elbe River, at Altengamm, Germany	60 600	2.15	....	Indefinite.	(55)
Danube River, at Vienna, Austria	39 212	8.86	July and August, 1897	Indefinite.	(50)
Po River, at Ponte Lagosiuro, (Italy)	27 027	9.10	....	Indefinite.	(52)
Elbe River, at Torgau, Saxony	22 040	6.73	....	Indefinite.	(55)
Elbe River, at Tetschen, Saxony	19 711	7.98	Sept., 1890	Indefinite.	(50)

Mr. Kuichling.

TABLE 37.—(*Continued.*)

Stream and locality.	Drainage area, in square miles.	Maximum discharge, in cubic feet per second per square mile.	Date of flood.	Number of years observed.	Authority.
Seine River, at Paris, France.........	16 859	5.24	Jan. 28, 1910	Indefinite.	(51)
Weser River, at Baden, Germany...	14 640	11.10 10.08	Jan., 1841 Mar., 1881	Indefinite. Indefinite.	(41)
Moldau River, at Prague, Austria......	10 404	13.48	Sept., 1890	Indefinite.	(50)
Main River, at Frankfurt, Germany..............	9 570	13.00 9.85 9.84	Jan., 1342 Mar. 31, 1845 Nov. 27, 1882	570	(57)
Moselle River, at Trier, Germany.......	9 200	17.28	....	Indefinite.	(47)
Weser River, at Hoya, Germany......	8 615	12.30	Jan., 1841	Indefinite.	(41)
Loire River, at junction with the Allier, France.........	6 945	26.44	——, 1846	Indefinite.	(62)
Weser River, at Hameln, Germany....	6 475	15.01	Jan., 1841	Indefinite.	(41)
Aller River, at Westen, Germany....	5 881	10.51	....	Indefinite.	(41)
Weser River, below the Diemel at Karlshafen, Germany.	5 730	15.71	Jan., 1841	Indefinite.	(41)
Durance River, at Bonpas, France.....	5 714	37.08 37.04	Nov 11, 1886 ——, 1843	7 (1882–88) Indefinite.	(44) (62)
Glommen River, at Elverum, Norway....	5 650	15.63	....	42 (1871–12)	(60)
Allier River, at junction with the Loire, France..........	5 548	30.00	——, 1856	Indefinite.	(62)
Aller River, below junction with the Leine River, Germany.	5 302	11.32	....	Indefinite.	(41)
Little Elbe River, at Brandeis, Germany...	5 052	5.04	Sept., 1890	Indefinite.	(50)
Weser River, above the Diemel at Karlshafen, Germany.	5 050	16.44	Jan., 1841	Indefinite.	(41)
Segura River, in Eastern Spain.........	4 830	10.8	....	Indefinite.	(22)
Durance River, at Mirabeau, France	4 533	52.20	Nov. 11, 1886	Indefinite.	(61)
Allier River, at Nevers, France.......	4 500	37.3	....	Indefinite.	(22)
Vistula River, at Cracow, Galicia.......	3 180	34.7	——, 1813	Indefinite.	(55)
Ems River, below Meppen, Germany.	3 173	8.43	Dec., 1880	Indefinite.	(41)
Mur River, at Graz, Austria.........	2 950	13.0	....	Indefinite.	(55)
Aller River, above junction with the Leine River, Germany.	2 788	10.45	....	Indefinite.	(41)
Fulda River, at Münden, Germany...	2 686	25.64	Jan. 18, 1841	Indefinite.	(41)
Fulda River, at Kassel, Germany.....	2 600	26.49	Jan. 18, 1841	Indefinite.	(41)
Rhine River, at entrance to Lake Constance, Switzerland...	2 555	48.4	....	Indefinite.	(55)

TABLE 37.—(*Continued.*)

Mr. Kuichling.

Stream and locality.	Drainage area, in square miles.	Maximum discharge, in cubic feet per second per square mile.	Date of flood.	Number of years observed.	Authority.
Leine River, above junction with the Aller River, Germany.	2 514	12.29	....	Indefinite.	(41)
Leine River, at Hanover, Germany.	2 022	12.76 16.25	Mar., 1881 ——, 1808	Indefinite. Indefinite.	(41) (41)
Ems River, at Meppen, Germany....	1 963	9.83	Dec., 1880	Indefinite.	(41)
Rhone River, at St. Maurice, Switzerland...............	1 812	12.47 17.40	——, 1897 ——, 1856	10 (1890-99) Indefinite.	(44) (44)
Glatzer Neisse River, at junction with the Oder, Germany........	1 759	24.70	July 26, 1903	Indefinite.	(44)
Bober River, at Sagan, Silesia, Germany..................	1 640	43.7	July 31, 1897	Indefinite.	(46)
Oder River, at Sagan, Silesia........	1 638	43.1	July 31, 1897	Indefinite.	(58)
Moselle River, at Toul, France..........	1 430	19.77	Oct. 23, 1880	Indefinite.	(47)
San River, Galicia, Austria.........	1 420	64.6	——, 1867	Indefinite.	(55)
Eder River, at junction with the Fulda, Germany.......	1 298	35.37	Jan., 1841	Indefinite.	(41)
Hase River, at Meppen, Germany....	1 210	6.16	Dec., 1880	Indefinite.	(41)
Verdon River, at junction with the Durance, France..........	932	62.90	Nov. 1, 1843	Indefinite.	(61)
Glatzer Neisse River, Silesia, Germany........	906	46.7	....	Indefinite.	(22)
Ardeche River, at junction with the Rhone, France.........	831	382.48	——, 1827	Indefinite.	(63)
Eder River, at Felsberg, Germany...	708	8.64	....	Indefinite.	(41)
Dreimel River, at Karlshafen, Germany.	681	40.45	Nov., 1890	Indefinite.	(41)
Werre River, at mouth, Germany...	575	48.14 32.18	Feb., 1799 Nov., 1890	Indefinite. Indefinite.	(41) (41)
Eder River, at Hemfurt, Germany...	552	58.0	....	Indefinite.	(22)
Buech River, at junction with the Durance, France......	552	84.57	Nov. 1, 1843	Indefinite.	(61)
Schwalm River, at junction with the Eder, Germany........	498	18.42	Jan., 1841	Indefinite.	(41)
Innerste River, at mouth, Germany...	477	15.53 24.74	Mar., 1881 ——, 1808	Indefinite. Indefinite.	(41) (41)
Bober River, near Mauer, Silesia......	467	90.8	July, 1897	Indefinite.	(59)
Pegnitz River, at Nuremberg, Germany.	459	33.1	Feb. 6, 1909	Indefinite.	(56) and (52)
Orne River, at Caen, France.........	449	19.67	Oct., 1880	Indefinite.	(62)
Oker River, near Braunschweig, Germany............	416	22.50	Mar. 11, 1881 and July 12, 1898	Indefinite.	(41)

Mr. Kuichling.

TABLE 37.—(*Continued.*)

Stream and locality.	Drainage area, in square miles.	Maximum discharge, in cubic feet per second per square mile.	Date of flood.	Number of years observed.	Authority.
Malapane River, at proposed dam site, Germany	403	26.3	....	Indefinite.	(22)
Hotzenplotz River, at junction with the Oder, Germany	392	76.94	July 21, 1903	Indefinite.	(44)
Ubaye River, at junction with the Durance, France	361	127.12	Nov. 1, 1843	Indefinite.	(61)
Coulon River, at junction with the Durance, France	352	100.33	Nov. 1, 1843	Indefinite.	(61)
Bleone River, at junction with the Durance, France	351	115.71	Nov. 1, 1843	Indefinite.	(61)
Sill River, at Innsbruck, Austria	330	9.63	....	Indefinite.	(44)
Moselle River, at Epinal, France	313	90.45	....	Indefinite.	(47)
Asse River, at junct. with the Durance, France	285	111.52	Nov. 1, 1843	Indefinite.	(61)
Wupper River at mouth, Westphalia, Germany	240	90.0	....	Indefinite.	(22)
Werre River, at Herford, Germany	238	13.80	Feb., 1799	Indefinite.	(41)
Wien River, at Vienna, Austria	216	81.3	Mar. 23, 1883	Indefinite.	(55)
Ardeche River, at Vans, France	215	525.63	——, 1890	Indefinite.	(63)
Bober River, at Rohrlach, Germany	204.6	160.1	July 30, 1897	Indefinite.	(48)
Queis River, at Lauban, Germany	187.4	161.2	July 30, 1897	Indefinite.	(46)
Ardeche River, at Aubenas, France	178.0	694.41	——, 1890	Indefinite.	(63)
Aupa River, near Slatina, Bohemia	158.6	73.46	....	Indefinite.	(22)
Weisseritz River, Saxony, Germany	148.0	69.0	July 31, 1897	Indefinite.	(48)
Bega River, near mouth, Germany	147.0	15.20	Jan., 1881	Indefinite.	(41)
Urft River, near Heimbach, Westphalia	145.0 145.0	24.7 24.4	Before 1897 ——, 1909	Indefinite. Indefinite.	(48) (22)
Dreimel River, at Marsberg, Germany	131.0	65.80	Nov., 1890	Indefinite.	(41)
Wupper River, at Barmen, Germany	122.0	83.37	Nov. 24, 1890	Indefinite.	(46)
Queis River, at Marklissa, Germany	118.0 118.0	262.7 233.3	Aug. 3, 1888 July 30, 1897	Indefinite. Indefinite.	(49) (46)
Jaispitz Creek, at Weirowitz, Austria	90.7	31.0	Mar., 1888	Indefinite.	(54)
Wupper River, at Dahlhausen, Germany	82.3	83.2	Nov. 24, 1890	Indefinite.	(48)
Queis River, at Greiffenberg, Germany	78.0	172.0	July 30, 1897	Indefinite.	(48)

TABLE 37.—(*Continued.*)

Mr. Kuichling.

Stream and locality.	Drainage area, in square miles.	Maximum discharge, in cubic feet per second per square mile.	Date of flood.	Number of years observed.	Authority.
Wilga Creek, near Cracow, Galicia....	52.1	65.1	....	Indefinite.	(55)
Holsterwitz Creek, at Gr. Olkowitz, Austria.	36.3	25.3	Mar., 1888	Indefinite	(54)
Bargaglino Creek, at Genoa, Italy..........	35.6	485	Oct., 1892	Indefinite.	(52)
Bargaglino Creek, at Genoa, Italy..........	35.6	421	July 18, 1908	Indefinite.	(52)
Eyach River, at Balingen, Wurtemberg....................	34.75	356.0	June 5, 1895	Indefinite.	(53)
Urnäsch River, St. Gallen, Switzerland...	30.0	153.03	....	Indefinite.	(44)
Goldbach, at Arnoldsdorf, Germany..................	19.7	268.88	July 21, 1903	Indefinite.	(44)
Queis River, near head, Germany....	12.34	358.0	July 31, 1897	Indefinite.	(58)
Little Aupa River, near head, Germany.....	11.9	385.63	....	Indefinite.	(22)
Furens River, at St. Etienne, France...	9.65	478.0	———, 1849	Indefinite.	(64)
Bargaglino Creek, above Genoa, Italy......	8.8	732.0	Oct., 1892	Indefinite.	(52)
Eyach River, near Margarethausen, Wurtemberg...........	7.34	788.8	June 5, 1895	Indefinite.	(53)
Dabrowka Creek, near Sambor, Austria...	5.02	253.2	....	Indefinite.	(55)
Eschbach, at Remscheid, Germany.	1.74	92.00	....	Indefinite.	(44)
Alfeldbach, at dam site, Alsace......	1.62	208.0	....	Indefinite.	(45)

Atlantic States, and is based on the greatest observed discharges of the Potomac River at Point of Rocks, Md., the New River at Radford, Va., the Catawba River at Rock Hill, N. C., the Little Tennessee River at Judson, N. C., Cane Creek at Bakersville, N. C., and numerous other streams which exhibit somewhat smaller rates of discharge than the preceding. This new formula is

$$q_{max.} = \frac{41.6\,(620 + M)}{24 + M} \qquad (3)$$

in cubic feet per second per square mile, and it may be regarded as applicable to mountainous and hilly water-sheds having areas of not more than 10 000 sq. miles, in the portion of the country indicated. In comparison with Iszkowski's data, as represented by the foregoing Equation (2), this formula gives $q_{max.} = 771, 242, 66$, and 44, respectively for $M = 10, 100, 1\,000$, and 10 000 sq. miles. A great difficulty is

Mr. Kuichling. found in estimating the discharge from cloudbursts on basins of less than 50 sq. miles, as both the duration of the heavy rainfall and the area covered by it are indefinite; hence it is likely that a modification of this new formula will also be required.

List of Authorities Referred to in Table 37.

I. References to American Streams.

Water Supply Papers of the United States Geological Survey, Washington, D. C., as follows:

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bücher, Vol. 28, 1899. (55) *Wochensch. d. Oester, Ing'r u. Arch. Vereines,* Vol. 9 (1884), pp. 33, 136, and 146. (56) *Ztsch. d. Oester. Ing'r u. Arch. Vereines,* 1911, p. 381. (57) *Das Städtische Tiefbauwesen in Frankfurt,* 1903. (58) *Engineering News,* 1911, II, p. 683. (59) *Engineering News,* 1913, I, p. 672. (60) *Engineering Record,* 1913, II, p. 583. (61) *Annales des Ponts et Chaussées,* 1892, 1st Sem., p. 1. (62) *Annales des Ponts et Chaussées,* 1897, 3d Trim. (63) *Annales des Ponts et Chaussées,* 1904, 3d Trim., p. 130. (64) E. Wegmann, Design of Dams, N. Y., 1911, p. 65. Mr. Kuichling.

AMERICAN SOCIETY OF CIVIL ENGINEERS

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PAPERS AND DISCUSSIONS

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CONCRETE BRIDGES: SOME IMPORTANT FEATURES IN THEIR DESIGN.

Discussion.*

By Wilson Fitch Smith, M. Am. Soc. C. E.

Wilson Fitch Smith, M. Am. Soc. C. E.—Referring to the authors' arguments in favor of the three-hinged arch and the subsequent discussion of its merits, it may be of interest to recall the masterful way in which the late George S. Morison, Past-President, Am. Soc. C. E., used the principles of arch design by applying the theory of the three hinges to a masonry arch of long span. Mr. Smith.

In 1900 Mr. Morison designed a masonry highway bridge of five arches, each with a span of about 180 ft. The arches were circular segments having a rise of one-quarter of the span. The bridge was 80 ft. wide and the arches extended for its full width. The arch ribs varied in depth from 5 ft. at the crown to 7 ft. at the springing line, and were to be of limestone with voussoirs of full depth on the faces of the arches. The arch rings carried cross-walls 4 ft. thick, spaced about 15 ft. apart, which, in turn, carried full centered arches supporting the floor, except at the three center panels where the spandrel was carried up solid to the floor level. At the crown joint and springing line joints were inserted lead bearings, about 1 ft. wide at the crown and 18 in. wide at the end joints. These plates were to act as hinges, permitting an adjustment of the arch under the dead-load strains, and the joints were to be filled with cement mortar after the completion of the bridge.

In the design of these arches the usual method was followed of dividing the arch ring into short sections, considering the weight of each as acting in a vertical plane through the center of gravity of each section. The weight of the spandrel arches and flooring was

* Continued from November, 1913, *Proceedings*.

Mr. Smith. divided in a similar manner. The strains were determined graphically, and by leaving voids of various sizes in the concrete filling over some of the spandrel arches and loading others with pig iron embedded in the concrete, an arrangement of loads was obtained which produced a resultant curve of pressure passing through the center line of the arch ring at each panel point under the cross-walls and at the hinge joints.

For various conditions of live load, the arches were considered as fixed (the hinge joints being filled before admitting traffic) and the resultant lines of pressure lay well within the middle-third of the arch rings, giving very moderate pressures for such large spans.

This treatment, in its simplicity and the skillful use of the three-hinge theory, is an example of the clear-sighted manner in which Mr. Morison approached problems of design, and shows the attributes of the great engineer.

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DERIVATION OF RUN-OFF FROM RAINFALL DATA.

Discussion.*

By Messrs. R. G. Clifford and Joel D. Justin.†

R. G. Clifford, Assoc. M. Am. Soc. C. E. (by letter).—Mr. Justin's attempt at furnishing a study of the relationship between precipitation and run-off which would lead to certain formulas applicable to water-sheds of varying characteristics is most praiseworthy, and his deductions apparently apply within fair limits to the water-sheds considered. Mr. Clifford.

In order to note certain danger marks in this mode of attack, the writer wishes to call attention to some of the data in the records furnished by Mr. Justin, and also to supplement his data with some from the far Western States, where conditions are somewhat different.

No equation, of course, is correct unless all the variables involved are introduced therein, but it may be that some of the conditions which change from year to year, or from one water-shed to another, are of such minor importance that their omission may not affect the result beyond the limit of accuracy desired, and it is this fact which has led the author to omit from his equation all but two of the eight variable conditions he mentions, namely, slope of water-shed and mean temperature.

Effect of Geology of Basin.—There are many cases where the geology of the basin has a marked effect on the run-off, as on the Pacific slope, where this element cannot be ignored in comparing one water-shed with another. The lava beds along the Pacific Coast, from the North Fork of the Feather River northward, are in themselves huge regulating reservoirs, which not only increase the summer flow, but actually tend to keep the total run-off for a whole season near the normal. For instance, the upper reaches of the North Fork of the

* Continued from November, 1913, *Proceedings*.

† Author's closure.

Mr. Clifford.

Feather River for the season, 1910-11, gave a run-off of 36 in. with a rainfall of 59 in., or 61%, and during the next year 19 in. of run-off was produced by 23 in. of rainfall, or 82 per cent. An exponential equation averaging most nearly the records for 1905 to 1913 for this water-shed would be $R = 2.2\ P^{0.7}$ (R being the run-off and P the precipitation).

Farther south, along the Sierra water-sheds, where granite peaks have replaced the lava beds, the exponential varies up to $P^{1.5}$. For the South Fork of the Yuba River at the Spaulding Dam, the average exponent is unity, the equation being $R = 0.74\ P$.

Straight-Line Equations for Run-Off.—The various water-shed data drawn on logarithmic paper by Mr. Justin, having been replotted by the writer on natural-scale co-ordinate paper, it is found that a straight-line equation of the form, $R = a\ P + K$, will fit all of them just as well as the logarithmic curves, but, of course, the introduction of two variables only complicates matters when comparing one water-shed with another. It is necessary, however, to keep the exponent below the second power for the majority of cases, for there are a limited number of regions where the rainfall varies only 20% above or below the normal, as indicated by the data presented. On the Pacific slope the variation is from 40% below the average to 50% above, and the use of the second power in Mr. Justin's equation gives values of run-off in excess of the rainfall for the wetter years.

The very marked variation in total run-off for different years having the same rainfall should not be overlooked. The records from Lake Cochituate, with a small water-shed, show an extreme case, and if the run-off had been based on the years, 1865 to 1872, inclusive, a very different constant would have been used. Even the large water-shed above the new Croton Dam furnishes such a variety of points that no two men would be likely to choose just the same line as an average, and the years, 1872 to 1880, inclusive, would form the basis for a very different one. There are many reasons for this variation in run-off for the same precipitation. As the author points out, the ground-water conditions and inaccuracy in true average rainfall are probably important factors, but, in addition, there are such modifying elements as dry winds and relative packing of the snowfall; the former cutting down the snow in a remarkably short time, and the more solid the snow pack, the slower the melting and the greater the percolation.

The Mass-Curve.—It is with regard to applying any formula to monthly precipitation on different water-sheds and thereby constructing a mass-curve to determine the necessary storage, that the writer feels that he cannot agree with Mr. Justin. In the first place, the exponential equation applied to the small monthly precipitations will not give the same yearly total as when applied to the total yearly precipitation, and it seems probable that the author intended merely to proportion the monthly rainfall to that for the whole year as computed

from his formula. Now, although the total run-off for a season for different water-sheds may depend mainly on mean temperature and slope, yet the ratio of summer flow to winter flow may be absolutely different. For instance, there are two branches of the same river, each having a water-shed of approximately 500 sq. miles and the same mean temperature, and yet the summer and winter flows of one have been, respectively, 560 and 10 000 cu. ft. per sec., though the second branch, in the same year, discharged 250 cu. ft. per sec. in summer and reached a maximum of 80 000 cu. ft. per sec. for the same winter flood as the other. Mr. Clifford.

This is undoubtedly a peculiar case, and is principally due to the geological formation, but, to some extent, it is also due to the fact that there is a greater proportion of one water-shed at the higher elevation receiving the precipitation in the form of snow.

A study of the actual and computed mass-diagrams of the Croton water-shed is hardly a convincing argument in favor of this mode of determining the storage needed, unless a very long time average is used and it is feasible to build a reservoir large enough to effect regulations over long dry periods.

Considering the draft line used for the Croton water-shed, if in 1880 a dam had been constructed based on the rainfall formula, a depletion of 18 in. would have to be provided for; and, if 20 to 30% in excess were allowed, there would have been a safety factor, over actual conditions to date, of 60%, which would have been rather extreme.

In a great many power projects it is either physically impossible, or very uneconomical, to store much more water than comes from the average low years, and in such cases the essential feature is to know just how much auxiliary power is required for the extreme years and how often they come. The safest procedure, if no river data at all have been kept, is to study the run-off from the nearest available water-shed, having a similar geological drainage basin, on which records can be obtained, using Mr. Justin's corrections for slope and mean temperature. A percentage allowance for extreme conditions can then be based on a study of such long-time results as given on the Croton mass-curve.

To obtain the storage needed for power purposes, the writer has used an empirical formula based on the available data for the South Yuba River, which, for that particular water-shed, checks remarkably well for the 8 years available. This formula has not yet been applied to any other water-shed, and so would be most unsafe to use elsewhere. The basis for the formula is the length of the dry season and the precipitation. It pre-supposes that run-off records have been kept carefully for at least one year, the storage needed for any other year being in this particular case proportional to the length of dry season corrected inversely by one-third of the difference in percentage, from the average precipitation of the season immediately preceding. By

Mr. Clifford. using the equation, $R = 0.74\ P$ (applicable to this river), the high points on a mass-curve can be located, and the low points can be plotted by means of the storage computed for each year, thus permitting of storage over long periods being found. The length of dry season is the most indefinite part of the proceeding, being the time of low stream flow, and is found approximately by records on other streams with similar geological formation, or, if a few years of monthly run-off and precipitation are available, by plotting these together and observing how the low-water flow follows the last heavy rains and picks up after the fall or winter storms.

Mr. Justin. JOEL D. JUSTIN, ASSOC. M. AM. SOC. C. E. (by letter).—That great caution is necessary in any attempt to predict the quantity of run-off from a water-shed, all engineers are agreed. That it is preferable to base calculations on the actual run-off, rather than on estimates founded on the rainfall of the water-shed is almost axiomatic. The methods and formulas presented in the paper are intended for use on water-sheds where run-off data are partly or totally lacking.

Given such a water-shed, one of two courses is open to the engineer desiring to build a storage reservoir: First, he may make a guess as to the run-off, taking it as a percentage of the rainfall, and being guided as much as possible by his judgment. Second, he may make a careful study of the conditions governing the relations of run-off to rainfall on the water-shed and on others having the same general characteristics, and, as the result of these studies, arrive at a run-off on which he may safely rely.

The formula derived by the writer is an attempt to reduce the second method to mathematical terms. Caution and judgment are necessary, of course, in using the formula, just as they are necessary in the use of formulas for, say, the design of a masonry dam. For instance, the writer would not attempt to apply the formula to the streams of California or Kansas without the possession of additional data.

Mr. Le Conte states that the formula gives the long average run-off. This is incorrect. The formula gives equally well the run-off for any particular year. In order to prove this, Tables 4 and 5 were prepared, showing that, in nearly all years, the agreement between the run-off computed by the formula and that recorded was remarkably close. It was even shown that usable mass-curves could be built up by the use of the formula. Mr. Le Conte points to a case in California where for 3 successive years there was no run-off. It is probable that the formula, if applied to this water-shed, would for these 3 years give such a small run-off as to be negligible.

Even on water-sheds where run-off data are available, it is necessary to use them with caution, as measurements of flow may be very inaccurate. The whole subject is one which does not permit of precision.

On Fig. 21 Mr. Begg gives a run-off curve for the rivers of Kansas,

Mr. Justin.

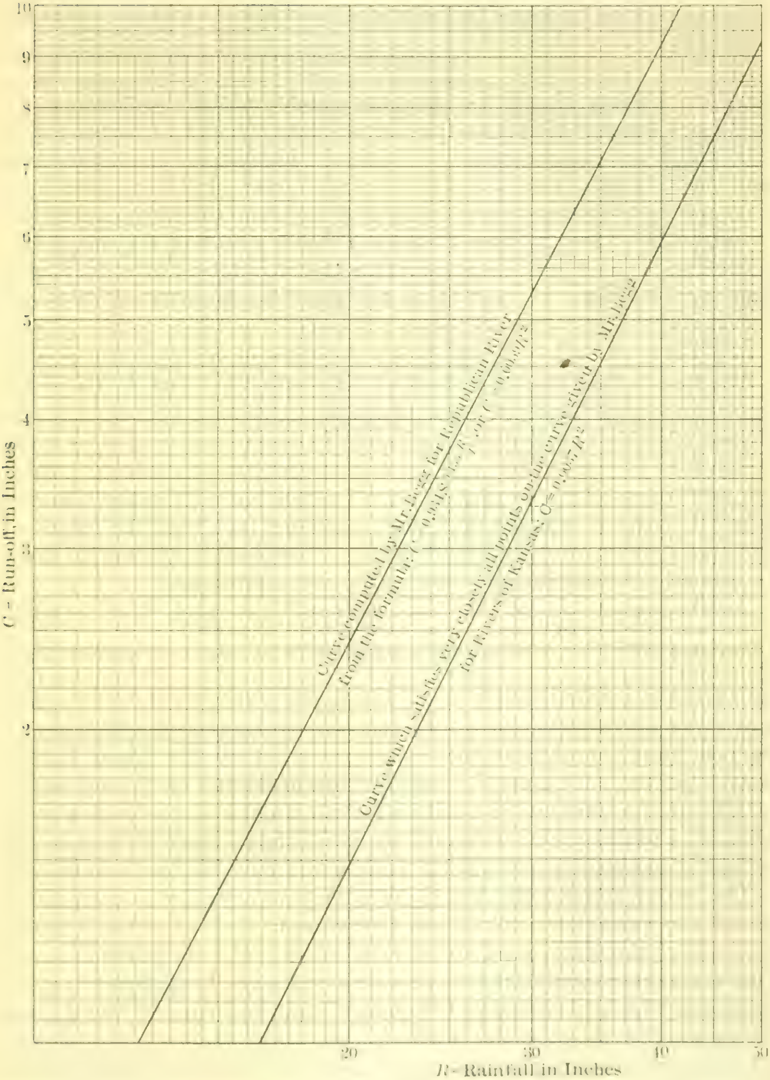

FIG. 25.

Mr. Justin. and states that nearly all points fall on or near this curve. This is a condition which is truly remarkable. In other parts of the country the discrepancy between even adjoining water-sheds is often as great as that shown by him between the run-off curve for all Kansas rivers and the curve plotted by him for the Republican River from the formula, $C = 0.934\ S^{0.155}\ \frac{R^2}{T}$. Accordingly, the prediction of run-off on the rivers of Kansas should be a very simple matter by the use of Mr. Begg's curve. He states that he has been unable to derive a formula which satisfies the relations shown by his curve. The writer presents the following equation which satisfies very closely all points on this curve: C = run-off, in inches; R = rainfall, in inches; then $C = 0.0037R^2$. Fig. 25 shows the logarithmic equation for this curve, together with the logarithmic curve for the Republican River, as computed by Mr. Begg. It will be noted that the curve is of the same general form as those presented in the paper for rivers in the Northeastern States, C being in all cases a function of R^2.

Mr. Begg states that the rivers of Kansas have a very much flatter slope than any of those of the Northeastern States. The slope of the Genesee (0.00554) is the flattest of any of those considered; it is about one-tenth of the slope of some of the steeper water-sheds for which data are presented. The general equation holds good for the Genesee. Hence the writer does not feel that the mere fact that the slopes of the Kansas rivers are less than that of the Genesee is sufficient to make the general formula inapplicable to Kansas conditions.

As the writer has pointed out, he would not apply this formula, $C = 0.934\ S^{0.155}\ \frac{R^2}{T}$, to other sections of the country without having available rainfall and run-off data with which to check the constant or to derive a new one. In the case of Kansas, for instance, it has just been shown that the curve presented by Mr. Begg has an equation of the same general form as those presented by the writer. If a study of the existing rainfall and run-off data of the region were made, it is probable that it would be found that a mere change in the coefficient would give practicable results for most of the water-sheds.

The writer agrees with Mr. Clifford that no equation is correct unless all the variables involved are introduced. In the writer's study, the slope of the water-shed and the mean annual temperature seemed to be the factors which had the greatest influence in determining the manner in which the relation between rainfall and run-off varied from one water-shed to another. Furthermore, these factors were capable of mathematical expression, whereas others, such as the geology of the drainage basis, were not. Hence these factors were used in determining the general formula. The effect of other factors, such as character of vegetation, extent of forest covering, prevailing winds, relative humidity, barometric pressure, etc., seems to be well within the limit of

accuracy of the existing data. At least this is the case with the drainage basins of the East. The writer regrets that he is not familiar with the water-sheds of the Pacific Coast; but is it not possible that other factors as well as the difference in the geology of basins might account for the discrepancy shown by Mr. Clifford? Difference in slope and mean annual temperature most certainly would account for a large part of it. Mr. Justin.

It is true that in many cases the relations existing between rainfall and run-off on a particular water-shed may be expressed by a straight-line equation, but this method makes every river a law unto itself, and, as Mr. Clifford states, "the introduction of two variables only complicates matters when comparing one water-shed with another."

With regard to the early records on the Croton and Lake Cochituate water-sheds, their accuracy is questionable. On the former, in the early days, there was only one rainfall station, but in recent years there have been five or six.

In the construction of the mass-curves presented, it was not the writer's intention to claim that monthly run-off could be predicted by using his formula, but merely to show that in spite of discrepancies from month to month, a usable mass-curve could be built up by this means.

In the case considered by Mr. Clifford, where storage is to be over a few dry months only, the method does not apply with the same force; but where the proposition is a big one and storage over dry years is considered, the method will give, as previously shown, practicable results.

With regard to the Croton water-shed, the greatest deficiency shown by the computed mass-curve is 18 in., the actual present storage on the water-shed is 16 in. In the past the actual draft has been somewhat less than that assumed; but this 16 in. of storage has been found to be so close to the danger line that New York City has several times been threatened with a water famine.

Greater storage could not be secured economically, and this factor, together with the constantly increasing draft, led to the installation of the Catskill supply at a cost of $161 000 000. Accordingly, the writer believes that the actual conditions check pretty well with the information that might have been obtained from a study of the mass-curve presented.

Any estimate of flow on a water-shed on which run-off data are non-existent is at best a scientific guess. The better the methods used, the better the prospect of approximating the actual run-off. Engineers should get away from the old-fashioned method of guessing run-off as a certain percentage of the rainfall because the particular water-shed happens to look somewhat like one which sometimes gave the percentage of run-off guessed at. They should attempt to predict run-off by a careful study of all the data available from surrounding water-sheds. It was as an aid in such a study that the present formula was derived.

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PAPERS AND DISCUSSIONS

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THE EFFECT OF SATURATION ON THE STRENGTH OF CONCRETE.

Discussion.*

By W. K. Hatt, M. Am. Soc. C. E.

W. K. Hatt, M. Am. Soc. C. E. (by letter).—The writer is interested in and appreciates Professor Van Ornum's experimental inquiry. An intelligent use of materials must be promoted by a knowledge of their underlying properties and essential nature. This knowledge is more likely to be gained by investigations of the character described in this paper than by elaborate and extensive empirical tests, mechanically planned and performed, which add to the work of the compiler and to the accumulation of débris that is carried along in textbooks and handbooks from one generation to another. Mr. Hatt.

The writer believes that, in this and also in a former paper,† Professor Van Ornum has failed to do justice to his tests, in that he has chosen not to accept the standards imposed by most experimenters upon themselves with respect to completeness of publication of the data. Every one knows that different persons may derive conflicting conclusions from the same data when the full circumstances are known. In the case of this paper, we must accept or reject deductions in respect to an important fundamental matter on the basis of a single diagram. The writer does not desire to be understood as saying that the diagram, with its experimental points and curve, is not the only expression of a law to be obtained from the data which are not published, but he expresses the wish that he, with others, might review the experimental facts independently. Much could also

* Continued from November, 1913, *Proceedings*.

† "The Fatigue of Concrete," *Transactions*, Am. Soc. C. E., Vol. LVIII, p. 294.

Mr. Hatt. be learned from a report of the measurements of deformations and sets. Only a partial view is obtained from the compressive strength alone.

In 1906-07 the writer conducted an investigation on the effect of the time element in loading reinforced concrete beams.* Table 2, from that source, shows a constantly increasing deflection under continued load applied to such beams, and also that a repeated application of load produces permanent deflection and set without affecting the subsequent maximum load carried by the beam. In the writer's view, these facts expressed a plasticity in concrete.

TABLE 2.—DEFLECTION OF REINFORCED CONCRETE BEAMS UNDER REPEATED LOADINGS.

Deflections and Set, in Inches.

Approximate stress in steel.	Load, in pounds.	Beam No. 12.			Beam No. 15.			Under constant load for five months. Deflection.	Set.	Ordinary testing machine load.
		Number of times applied.	Deflection.	Set.	Times applied.	Deflection.	Set.			
3 000	2 400	1	0.025	0.005	1	0.025	......	0.130	0.06	0.050
		710	0.035	0.005	...	......	......	0.210		
8 000	5 200	1	0.070	0.010	1	0.070	0.010	0.160	0.13	0.08
		500	0.170	0.060	500	0.140	0.050			
16 000	6 750	1	0.210	0.060	1	0.180	0.060	0.290*	....	0.14
		700	0.260	0.100	450	0.240	0.080			
29 700	8 100	1	0.300	0.100	1	0.270	0.090	0.490	0.36	0.21
		470	0.310	0.120	620	0.290				

* Two months.

In these cases the results could hardly be explained by the effect of water in softening the concrete, as reported by Professor Van Ornum. The beams were exposed outdoors, were protected from rain by a platform, and were tested under repetitive loads in the laboratory.

In arriving at a final view, some help is obtained from the behavior of other materials. The writer has noted an analogy between the behavior of concrete and wood with respect to the effects of certain conditions of loading.

In case of any material, one should know the effect of the following elements on the strength and deformation, both elastic and plastic:

(1). Time-rate of application of stress, including impact loading and long-continued steady loads;

(2). Moisture conditions;

(3). Temperature of material under (1).

* "Notes on the Effect of Time Element in Loading Reinforced Concrete Beams," *Transactions*, Am. Soc. for Testing Materials, Vol. VII, 1907.

(1). Wood exhibits an increasing deformation and set under loads which are continued over periods of days and weeks, and the final load is not affected by precedent sets. Mr. H. D. Tiemann has investigated this matter exhaustively.* Portland cement concrete also possesses this property. Mr. Hatt.

As the speed of application of the load is increased, wood exhibits a higher elastic limit, which, under impact, may be double the static elastic limit. It is evidently affected by the time-rate of the application of loading. No data are known to the writer to determine the effect of speed of loading on concrete.

The final strength of both wood and concrete appears to be unaffected by precedent plastic changes which produce set.

(2). Wood also becomes more plastic when the wood substance contains more water. It is strong and stiff when dry, and weak and flexible when wet. Omitting the difference of the chemical action proceeding in concrete when in water, it appears from Professor Van Ornum's paper that concrete becomes weak when saturated with water. His deformation measurements, not reported, might show whether or not the modulus of elasticity was correspondingly decreased.

After wood is dried out and the excess moisture is removed, it nearly resumes its original properties. Professor Van Ornum suggests that concrete would regain something more than its original strength if dried out after being completely saturated.

(3). No data are known to the writer to show conclusively the effect of temperature on the strength and deformation of either wood or concrete.

The foregoing discussion indicates that the binding substance in wood and concrete exhibits marked plasticity, not alone under long-continued loadings at low stress, and that this substance is temporarily affected by the absorption of water.

Leaving the field of the writer's knowledge, he would take the liberty of referring to the views of others who consider the hardening of concrete as a phenomenon of colloidal action, and to the statement of those wise in the knowledge of wood substance that a colloidal material binds wood structure together. If this is so, we might expect, from the properties of colloids, that concrete and wood would show the noticed plasticity under long-continued loadings, the noticed effect of moisture on the strength; both should show a difference of behavior under quickly applied loads; and their strength should also be affected by temperature—being more brittle at low temperatures. The writer may be pardoned for sketching in this uncertain field.

* A report of part of his investigations will be found in *Transactions*, Am. Soc. for Testing Materials, Vol. IX (1909), p. 534, "Some Results of Dead Load Bending Tests of Timber by Means of a Recording Deflectometer"; and Vol. VIII (1908), p. 541, "The Effect of the Speed of Testing upon the Strength of Wood and the Standardization of Tests for Speed."

Mr. Hatt. Do not the author's results bear out the common view of workers in concrete that some part of the hardening of the concrete floor of a building under construction when exposed to the drying conditions of the atmosphere is due to this "drying out", irrespective of temperature? The writer has noticed the rapid gain in strength of concrete specimens shipped to the laboratory in tin forms after the latter had been removed. Specimens of concrete taken from building failures also gain strength rapidly when exposed to the air of the laboratory. This is no doubt due to hastened chemical action consequent on the increased temperature, but it also may be the process of drying out analogous to that prevailing in wooden beams. Professor Van Ornum coincides in this common view in his statement:

"In fact, the failures which have occurred are generally a result of several such contributing causes. The writer believes that the considerable weakening produced by the saturation of dry concrete has invariably been a contributing factor in all those instances in which there was an active wetting of dry or partly dry concrete when subjected to essential stresses."

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MEASUREMENT OF THE FLOW OF STREAMS BY APPROVED FORMS OF WEIRS WITH NEW FORMULAS AND DIAGRAMS.

Discussion.*

By Messrs. E. A. Moritz, Allen Hazen, Clarence T. Johnston, and R. B. Robinson.

E. A. Moritz, Assoc. M. Am. Soc. C. E. (by letter).—In making analyses of all the data and preparing this paper the author has performed a monumental task which, no doubt, will receive the cordial appreciation of all hydraulic engineers. Mr. Moritz.

The author states that "the method of calculating the discharge over a weir should be the simplest that can be found; in other words, it should give the most accurate results with the smallest amount of work", and he advocates the sharp-crested weir without end contractions as most nearly fulfilling these requirements. The writer agrees with the statement in so far as the accuracy of the results is concerned, provided the height of the weir crest is properly determined each time a measurement is made or the approach channel is kept free of silt; but either of these requirements necessitates considerable care and effort, so that the author's statement is open to serious question. The writer has in mind an irrigation project, typical of many, on which the use of the sharp-crested weir without end contractions would be practically impossible on account of the large quantities of silt carried at certain seasons of the year, which would necessi-

* This discussion (of the paper by Richard R. Lyman, Assoc. M. Am. Soc. C. E., published in the September, 1913, *Proceedings*, and presented at the meeting of November 19th, 1913), is printed in *Proceedings*, in order that the views expressed may be brought before all members for further discussion.

Mr. Moritz. tate either cleaning out the approach channel at frequent intervals or determining the height of the crest at each measurement. Either alternative is impracticable, as any one knows who is familiar with irrigation projects having from 1 000 to 2 000 or more measuring weirs. This example is selected because the author evidently had in mind the use of the weir which he advocates for the measurement of irrigation water, for he says: "the sharp-crested weir without end contractions can certainly be used to best advantage in all irrigation projects".

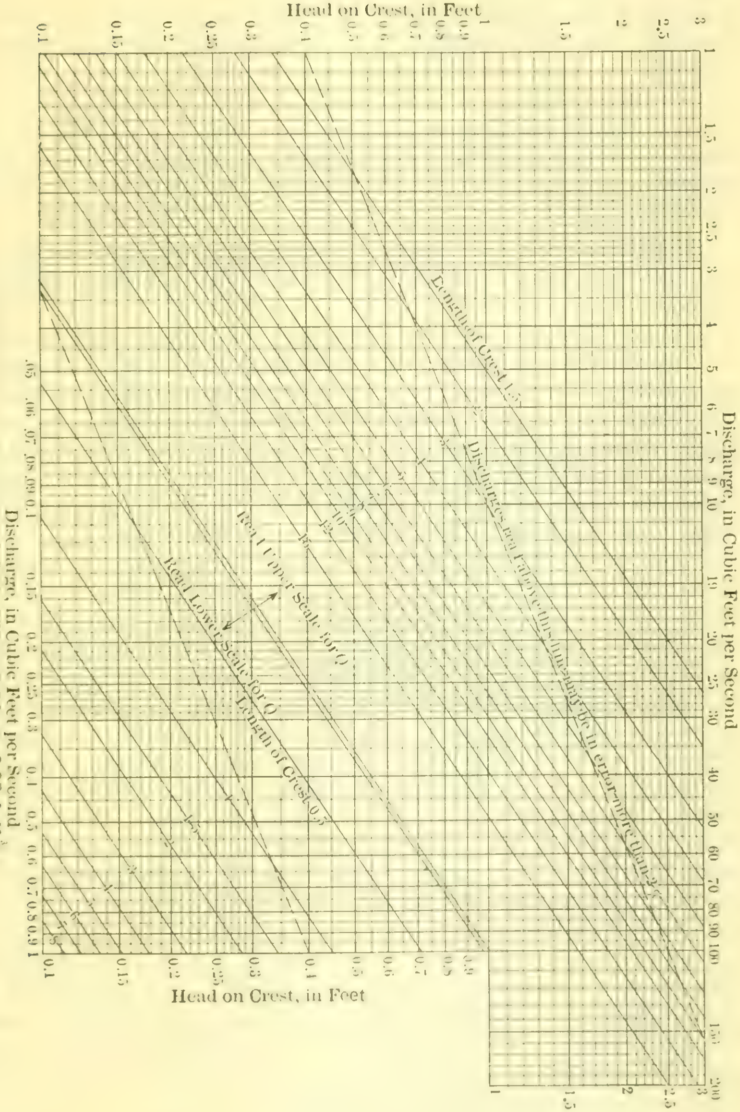
For this purpose the Cippoletti weir offers a simple, convenient, and accurate method, and is used probably more than any other type. The construction of the Cippoletti weir is fully as simple as the suppressed weir, if not more so, notwithstanding the author's statements in this regard. In most cases a pool of sufficient size can be excavated above the weir to avoid any but negligible velocities of approach, and one or two good cleanings of the pool during a season will generally suffice. For this weir, tables or diagrams can be prepared which will give at a glance the discharge for any measured head, or, as is frequently necessary, the head can be read which will give any required discharge. Fig. 46 represents such a diagram for Cippoletti weirs, and Fig. 47* is for contracted and suppressed weirs with vertical sides (Francis' formula). The importance of simplicity in this regard cannot be exaggerated, on account of practical considerations. The measurements and care required for the accurate use of the author's diagrams vitiate to a large extent their practicability, although they should be exceedingly useful for the more scientific works.

For contracted weirs, the discharge given by the diagram, Fig. 47, may be in error 4% or more, if the head is greater than one-third of the length of the crest. The discharge over suppressed weirs is given directly by the upper and lower scales. To obtain the corresponding discharge over a contracted weir, subtract the value read from the curve marked "Value of 0.666 $H^{\frac{5}{2}}$, using the upper or lower scale, as indicated.

It may be insisted that the use of the Cippoletti weir obtains simplicity at too great a sacrifice of accuracy. In regard to this, there is considerable evidence in recorded experiments that both Cippoletti and fully contracted weirs give results within an error of from 2 to 4% when the head is not greater than one-third of the crest length, which condition can readily be obtained. Of the two, the Cippoletti weir gives the more accurate results. The quantities in these experiments were measured volumetrically, thus avoiding any possible error due to the use of a calibrated measuring device for determining them.

* Francis formula for contracted rectangular weirs, $Q = 3.33\ H^{\frac{3}{2}} (L - 0.2\ H)$, may be written $Q = 3.33\ L\ H^{\frac{3}{2}} - 0.666\ H^{\frac{5}{2}}$, or $Q =$ (Discharge over suppressed weir) $- 0.666\ H^{\frac{5}{2}}$

Mr.
Moritz.



DISCHARGE OF STANDARD CIPPOLETTI WEIRS $Q=3.37\,L\,H^{\frac{3}{2}}$

FIG. 46.

Mr. Moritz. such as the "standard weir" used in the Cornell experiments, of which the author says "the results it gives can be accepted as accurate to within 2 or 3 per cent."

In the writer's opinion, there is no better practical device, at present available, than the Cippoletti weir for measuring the quantities encountered in the majority of irrigation laterals.

The author says:

"For finding the discharge over a weir, the diagram has two advantages over the formula: First, it gives results without computation; secondly, results obtained by the diagram do not appear to contain an accuracy which is not warranted."

This is true, not only for weir discharges, but also for most other hydraulic computations involving the use of more or less complicated formulas.

Concerning the question of discharge over broad-crested weirs, the writer would like to obtain some additional light. What is said in the following is not offered in a spirit of criticism, but the writer has had occasion to use the results of the Cornell experiments for calculating discharges over broad-crested weirs, and has found that the results deduced therefrom by different persons do not always agree; in fact, the disagreement is so great in certain cases that an explanation seems to be required. Three sets of results from these experiments have now been published: by Mr. Lyman, by Gardner S. Williams, M. Am. Soc. C. E.,* and by R. E. Horton, M. Am. Soc. C. E.†

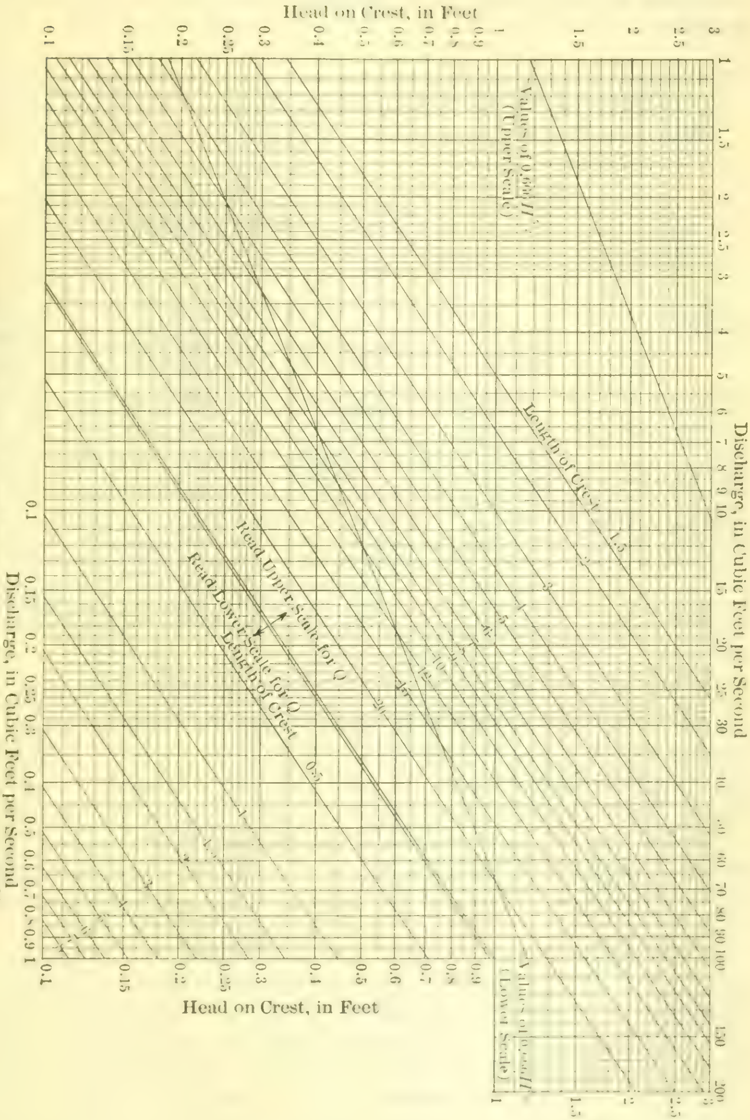
The writer has selected at random several types of the broad-crested weir on which experiments were made, and has set down the comparative figures given by the three investigators for the discharge for corresponding heads. The results are shown in Table 68. The figures represent the factors by which the results computed from Bazin's formula for sharp-crested weirs without end contractions must be multiplied in order to obtain the discharge over the particular broad-crested weir; these figures are given directly by Messrs. Williams and Horton. To obtain the corresponding figures from the author's diagrams, the writer read the discharges from the diagrams (Plates XC and LXXXV), and divided these by the corresponding figures, as calculated by Bazin's formula.

Model XXXIII.—For the author's Model XXXIII the figures in Table 68 show a substantial agreement, although for a head of 0.5 ft., Messrs. Horton and Williams disagree by about 3% and Mr. Lyman practically agrees with Mr. Williams. For a head of 3.5 ft. no two agree, the maximum difference being between Messrs. Horton and Lyman and amounting to about 2 per cent.

* "American Civil Engineers' Pocket Book," p. 869, and elsewhere.

† Water Supply Paper, No. 200 (revision of Water Supply Paper, No. 150) of the U. S. Geological Survey.

Mr. Moritz.



DISCHARGE OF STANDARD SUPPRESSED RECTANGULAR WEIRS: $Q = 3.33\,L\,H^{3/2}$

DISCHARGE OF STANDARD CONTRACTED RECTANGULAR WEIRS $Q = 3.33\,L\,H^{3/2} - 0.666\,H^{5/2}$

FIG. 47.

Mr. Moritz.

Model XXX.—In Model XXX there is a close agreement between Messrs. Williams and Lyman, but, for a head of 4 ft., Mr. Horton differs from both by about 6%, the differences being less for heads smaller than 4 ft.

TABLE 68.—FACTORS BY WHICH THE RESULTS COMPUTED FROM BAZIN'S FORMULA FOR SHARP-CRESTED WEIRS WITHOUT END CONTRACTIONS MUST BE MULTIPLIED IN ORDER TO OBTAIN THE DISCHARGE OVER BROAD-CRESTED WEIRS.

Model.	Author.	HEAD ON WEIR, IN FEET.							
		0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
XXXIII	Williams	0.971	1.040	1.083	1.105	1.118	1.128	1.136	1.144
	Horton	0.941	1.039	1.087	1.109	1.118	1.120	1.127	1.123
	Lyman	0.967	1.032	1.067	1.114	1.130	1.143	1.152	1.140
XXX	Williams	0.968	1.008	1.032	1.041	1.043	1.044	1.045	1.046
	Horton	0.947	1.000	1.036	1.063	1.085	1.096	1.108	1.110
	Lyman	0.967	0.985	1.030	1.040	1.048	1.045	1.050	1.043
XLVI	Williams	0.797	0.812	0.821	0.821	0.816	0.813	0.810	0.808
Flat top	Horton	0.792	0.795	0.796	0.815	0.844	0.870	0.90	0.93
b = 3.17 ft.	Lyman	0.785	0.795	0.792	0.823	0.852	0.866	0.887	0.898
XLIII and XLIII*a*	Williams	0.783	0.792	0.797	0.795	0.789	0.784	0.780	0.777
Flat top	Horton	0.790	0.790	0.792	0.793	0.793	0.791	0.791	0.789
b = 16.29 ft.	Lyman	0.785	0.803	0.801	0.792	0.780	0.786	0.792	0.788
XLI	Williams	0.819	0.879	0.910	0.925	0.932	0.938	0.942	0.947
Flat top	Horton	0.806	0.808	0.878	0.906	0.985	1.00	1.00	1.00
b = 1.65 ft.	Lyman	0.785	0.825	0.891	0.933	0.965	1.00	1.009	0.995

Model XLVI.—The greatest variation is found in Model XLVI, having a flat-top crest 3.17 ft. wide, where the difference between Messrs. Williams and Horton for a 4-ft. head amounts to about 13%, the differences decreasing as the head decreases. Messrs. Horton and Lyman agree much better, but they also show quite large differences.

Models XLIII and XLIIIa.—For Models XLIII and XLIII*a*, having a flat-top crest with a width of 16.29 ft., all three investigators are in substantial agreement, the differences for any head being very small.

Model XLI.—For the narrow flat-top crests the disagreements become very large. In Model XLI, with a width of 1.65 ft., the maximum disagreement is between Messrs. Williams and Horton for a head of 1 ft., the difference being about 8%, and the disagreement between Messrs. Williams and Lyman for a head of 3.5 ft. is nearly as large.

If differences in the interpretations of the experiments running as high as 13% are justifiable, the writer wishes to ask what degree of accuracy may be expected in practice in calculating the discharge over a broad-crested weir, or in designing a weir to produce a given

discharge? No doubt others who have occasion to use these results would be glad to have information on this point, and it is hoped that the author will be able to explain the discrepancies above noted so that the results of these experiments may be used with a greater degree of confidence than now seems warranted. Mr. Moritz.

Allen Hazen, M. Am. Soc. C. E. (by letter).—The Society is indebted to Mr. Lyman for an extremely interesting and ingenious comparison of the most important weir measurements made by various experimenters up to the present time. Plate LXXXI,* showing the percentage variation of all the different experiments, gives a more concise view of the whole subject than is to be obtained elsewhere. Plate LXXX,* showing the discharge over weirs, is most ingenious, and may be accepted as an authoritative compilation of the best existing data. The methods of plotting by which small differences are shown on a larger scale is to be taken as by no means the least of the good things in the paper. Mr. Hazen

Notwithstanding the use of exponential formulas and the author's statements in regard to them, the writer believes that there are still advantages in the use of a formula which can be solved with an ordinary Mannheim slide-rule, where the conditions permit a reasonable accuracy to be so obtained. In the case of weirs, this can be done, because the discharge over weirs follows more or less closely the 1.5 power of the head, and the 1.5 power can be obtained rapidly and accurately with the slide-rule.

There is one fundamental proposition in regard to weirs that the writer has used for years and believes to be correct, which does not enter into the analysis of the data used by the author. This is: that two weirs of different size but of the same relative proportion in all their parts, that is to say, with the same ratio between the height of the weir, the depth of water over the weir, and the distance back from the weir that the head is measured, and with crests (if not standard sharp-edged crests) of the same proportionate dimensions, will always give discharges in proportion to the 1.5 power of the heads. In other words, such similar weirs of different sizes will have the same value of C in the formula, $Q = C\ h^{1.5}$. As far as the writer knows, the only evidence of substantial divergence of experimental results from this relation is in the case of a few experiments with very low heads. It may be that the viscosity of water in these cases is a disturbing element and accounts for these divergencies. We know, from data on the flow of water in pipes, that the viscosity of water has only to be reckoned with at low velocities, and disappears rapidly and completely as the velocities are increased. If these divergencies with low heads are really due to the viscosity, no appreciable effect from it is to be

* *Proceedings*, Am. Soc. C. E., September, 1913.

Mr. Hazen. anticipated at the higher heads for which calculations are most frequently made. The fraction, $\frac{0.0148}{h}$, in the Bazin formula, and the arbitrary addition of 0.007, in the Fteley and Stearns formula, are the practical indications of these divergencies at low heads. Except for this feature, both the Bazin and the Fteley and Stearns formulas are based on the above stated proposition as applied to a standard weir.

If the proposition is accepted that weirs which, in all respects, are proportional to each other will have the same coefficients, then the distance back from the weir at which the head is measured should also be in proportion to the height of the weir. Using an arbitrary distance of 15 ft. seems to be illogical; and for very small weirs most inconvenient. Following Fteley and Stearns' statement, the minimum distance for such measurement is to be taken as 2.5 times the height of the weir. As both convenience and accuracy will be favored by as short a distance as is permissible, the writer suggests that it would be better to measure the head in all cases at a distance back from the weir equal to 2.5 times the height of the weir.

Francis, in deducing a formula from his experiments, used an arbitrary method of allowing for the velocity of approach, which he stated was probably below the truth. As the velocities to be allowed for in his experiments were always low, the influence of this error on the formula which he deduced was not great. Afterward, Fteley and Stearns proposed a method of allowing for the velocity of approach which was based on their own carefully made experiments on this particular point. They pointed out that, if the Francis results were recomputed with the allowance which their experiments indicated to be proper, the results obtained were practically identical with their own. In other words, the experimental results of Francis and of Fteley and Stearns were completely in accord.

The Bazin formula differs from these two in making a much greater allowance for the deviations at low heads, and in providing a more convenient means for taking into account the velocity of approach. The allowance in it for deviations at low heads is much greater than is indicated by Fteley and Stearns' experiments, the latter seeming to have been more exhaustive on this point than were those of Bazin. Between these two formulas, that of Fteley and Stearns would seem to deserve preference for general use, were it not for the cumbersome and inconvenient method of allowing for the velocity of approach.

The deviations at low heads can better be considered as a separate matter. Considering the relative ease with which experiments to determine the discharge at low heads can be carried out, it is surprising how little exact knowledge exists as to these quantities, and the influence on them of the temperature and the character and exact shape of the lip.

It may be that the desire to produce a formula which would account for the results at low heads as well as at high ones has led to greater complexity than is really necessary in a formula to be used only for higher heads. To see if it would not be possible to find one of more simple form, which would account for the data, a number of formulas were tried by the writer. The general form, $Q = \left(k + a\frac{h}{p}\right)h^{1.5}$, was selected as worthy of further study. From Fteley and Stearns' experiments, the approximate value of a was found to be 0.5; then $Q = \left(k + 0.5\frac{h}{p}\right)h^{1.5}$, in which the value of k remains to be determined. The values of k in the formula, in order to account for the various experiments of Francis, and of Fteley and Stearns, with weirs without end contractions and with heads of more than 0.3 ft., were found by approximate slide-rule calculations, and these results are shown in Fig. 48. Mr. Hazen.

In the experimental results of Fteley and Stearns used to show the effect of different heights of weir, the absolute quantities are not given. In each of these cases the first experiment, that is, the one with the highest weir, was used to compute the quantity of water for all the experiments in that series, and from this quantity the values of k for the remaining experiments in that series were computed.

On Fig. 48 have also been plotted some values of k corresponding to the exact solutions of the Fteley and Stearns and Bazin formulas, for conditions which are indicated. There is also drawn a straight line corresponding to the value of k which best represents all the experimental data, and also lines showing 1% errors or variations in quantity of discharge from the line drawn. This method of plotting is somewhat similar to that used by Mr. Lyman, to whom acknowledgement is made.

It is seen from all this that the formula, $Q = \left(3.27 + 0.5\frac{h}{p}\right)h^{1.5}$, accounts for all the Francis results, and nearly all the Fteley and Stearns results where the head exceeded 0.3 ft., within 1%, and it seems to serve quite as well in this particular as any formula that has been proposed.

The Bazin formula indicates a much wider divergence between the coefficients with high heads and low heads, and in this respect is not supported by the Fteley and Stearns experiments.

This simplified formula, which produces results that differ but slightly from those obtained by the Fteley and Stearns formula when velocity of approach is allowed for, has the great advantage over it that it can be easily solved on a slide-rule, automatically allows for the velocity of approach, and accounts for all the experimental results

Mr.
Hazen.

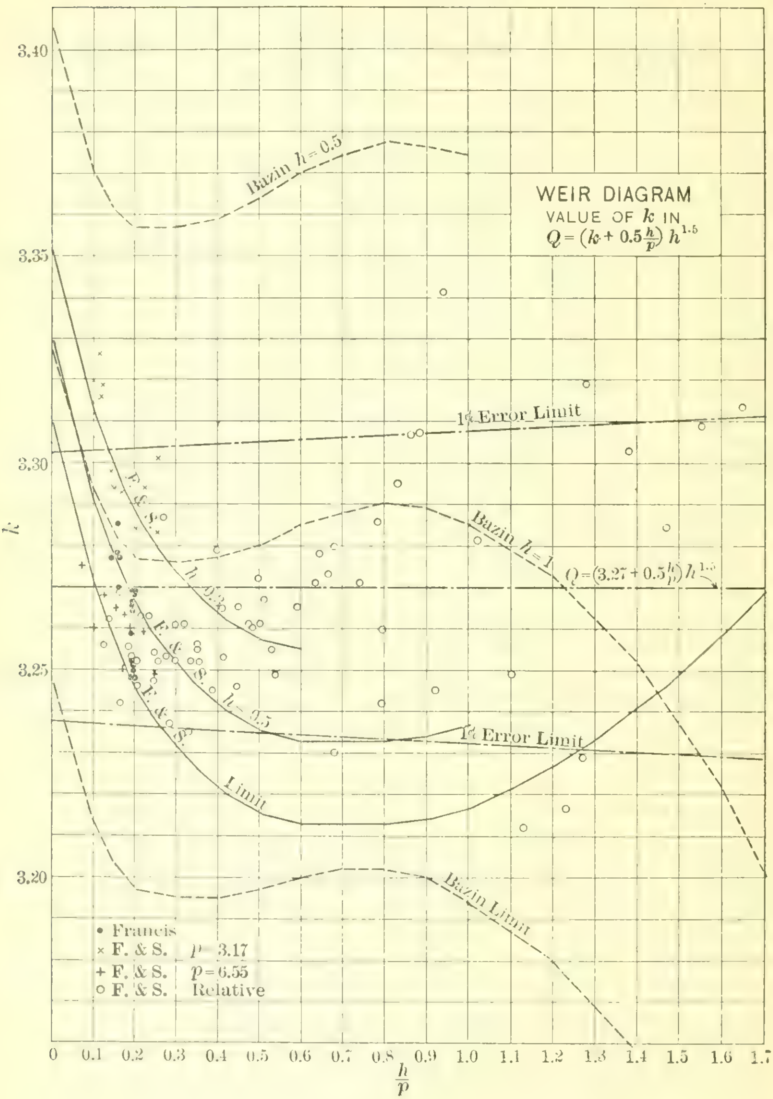


FIG. 48.

with heads greater than 0.3 ft. as well as the original formula. As compared with a diagram like Mr. Lyman's, it has the advantage of allowing results of all needful accuracy to be taken off for intermediate values of p and h for which interpolation in even so good a diagram as that of the author may sometimes lead to greater errors than are desirable. Mr. Hazen.

CLARENCE T. JOHNSTON, M. AM. SOC. C. E. (by letter).—It is fortunate that a man qualified to discuss the measurement of flowing water has undertaken a study of this subject. Mr. Lyman has brought together the available material relating to the actual measurement of water flowing over weirs of various kinds, and the diagrams and formulas he has presented must be very helpful to the Engineering Profession. Mr. Johnston.

His investigations have led him to recommend the rectangular weir without end contractions, and he advises legislation which will make this form of weir a standard. This would seem advisable, assuming that weirs can be used wherever flowing water is to be measured. The streams of Utah and the rivers and many of the ditches and canals of the West have sufficient fall to make weirs generally feasible. In many places, however, the fall is insufficient, and there, the measuring flume, which is rated by actual current-meter gaugings, must be used. Those who have used weirs extensively know how difficult it is to maintain them so that they furnish uniformly correct results at all times. It might be possible, in some cases, to place the weir in a channel running parallel to the canal or natural stream and have gates which would enable those in charge to divert the water over the weir only when measurements were being made. This would avoid some of the troubles that generally arise. Under these conditions, the structure in which the weir is placed can be inspected, and those in charge can ascertain whether or not water may pass around or under it. They can clean the channel prior to the beginning of any test, thus maintaining a constant height of the crest of the weir above the bed of the waterway. The natural channel upstream from the weir will not be changed greatly by erosion, if water runs through it only at intervals. It would seem that, in establishing a legal measuring device, precautions should be taken so that such device may have general application and so that, wherever it is used, engineers would have general confidence in the results obtained.

Plate LXXX,* and those following, relating to the discharge of various kinds of weirs when the head and the height of the crest are known, are the most satisfactory diagrams of the kind thus far published.

* *Proceedings*, Am. Soc. C. E., September, 1913.

Mr. Johnston. Plates LXXXVIa and LXXXVIb,* together with the text describing them, deserve special mention. The text, even with the examples given, does not show the basic theory of the method used. It is possible that Mr. Lyman feels that the underlying theory is so elementary that a discussion thereof is not advisable. Under such an assumption, however, his numerical examples and some descriptive matter might have been eliminated.

He takes for his general equation, $Q = mh^n$, which, when reduced to logarithmic form is log. $Q = n$ log. h + log. m. The latter equation, when plotted on rectangular axes, represents a straight line, as he mentions. Certain measurements have been made in practice, which establish points referred to these axes in terms of log. Q and log. h. Approximate values of m and n are known, so that it is possible to substitute these values in the foregoing equation, and this Mr. Lyman calls the "trial" formula. When the actual measurements are considered it is found that, for any value of log. h, the discrepancy between the measured and computed values of log. Q is very small. In order to show the discrepancies, the values plotted for log. Q must be shown on a very large scale. This is almost impossible. In addition, the lines lie so close to the axis of log. Q that the intersections with that axis are hard to locate. Mr. Lyman says: "Hence, the differences in the values of log. Q cannot be shown with sufficient accuracy on a drawing of reasonable size when rectangular axes are used." This is an accurate statement of the situation, except that there is no apparent reason for using axes which are not rectangular, and it would seem to one who has not given extended study to the problem that Mr. Lyman continues to use rectangular axes.

Referring to Fig. 49, the logarithmic equation has been plotted on the rectangular axes, log. h and log. Q. The equation takes the form

$$\text{log. } Q = \frac{a + b}{c} \text{ log. } h + b \text{. . . . . (1)}$$

The scale to which the values of log. h and log. Q are plotted, may be fixed to suit the problem under consideration. In Fig. 49, AB represents the line established by the "trial" formula. It is impracticable to plot values of log. Q to the fourth decimal place, measuring from the axis of log. h. If this were feasible, the values, a and b, would be shown on the same scale and for any values, k, k', etc., for log. h and S, S', etc., for log. Q, the location of the line showing the relation of log. h and log. Q, as measured, could be established. Instead, we subtract the values of log. Q as measured from those computed for various values of log. h. This gives us s, s', etc. These are shown on Fig. 49, and they might be laid off from the line representing the "trial" formula as before, if it were not for the objections stated.

* *Proceedings*, Am. Soc. C. E., September, 1913.

Instead of laying off these differences from that line, we will lay them Mr. Johnston.
off from the line log. $Q = b$, as shown in the diagram. This locates the line, EF. This line is actually located by drawing a straight line in such a way as to approximate a number of the points established by the measurements. Two points, however, fix the line, and it is always possible to select two points on the line after it is drawn, regardless of how many measurements it may represent. The equation of the line, EF, is:

$$\log. Q = \frac{s' - s}{k' - k} \log. h + b + \frac{k' s - k s'}{k' - k} \quad \ldots\ldots\ldots\ldots (II)$$

when referred to the same rectangular axes.

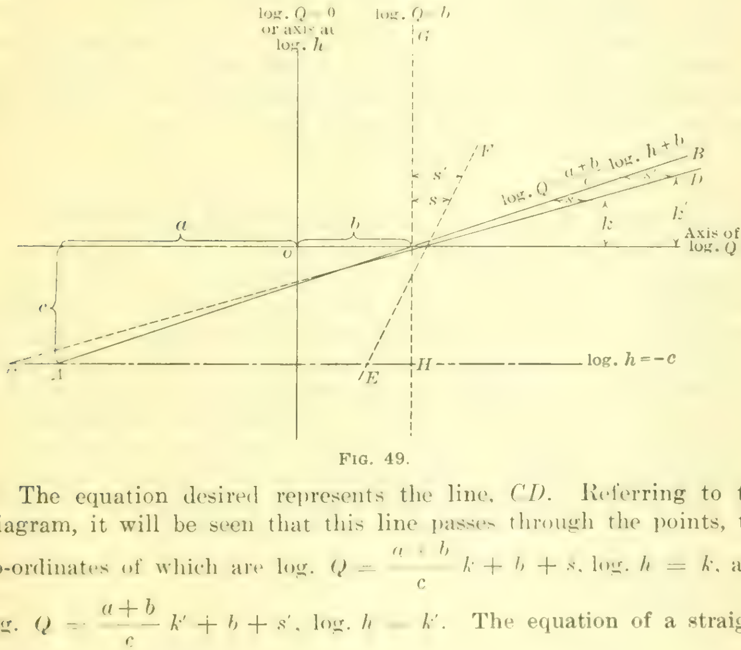


FIG. 49.

The equation desired represents the line, CD. Referring to the diagram, it will be seen that this line passes through the points, the co-ordinates of which are log. $Q = \frac{a+b}{c} k + b + s$, log. $h = k$, and log. $Q = \frac{a+b}{c} k' + b + s'$, log. $h = k'$. The equation of a straight line through these two points is

$$\log. Q = \left(\frac{a+b}{c} + \frac{s' - s}{k' - k}\right) \log. h + b + \frac{k' s - k s'}{k' - k} \quad \ldots . (III)$$

Now, in examining Equations I, II, and III, we find that the tangent of the angle between the line represented by Equation III and the axis of log. h is the sum of the tangents of the other two lines, and that in both Equations II and III the intercepts on the axis of log. Q are the same. Therefore, to find the equation of the line representing the measurements, CD, we first obtain Equation II representing the

Mr. Johnston. line, *EF*. Add the tangents shown by the equation for the line, *AB*, and the line, *EF*, and we have the tangent in Equation III. We preserve the intercept as shown by Equation II for Equation III.

Regardless of how small the differences may be between computed and observed quantities, such differences may be laid off as shown on such a scale as will enable them to be read to any desired number of decimal places. The line or lines thus established enable us to write the equation of the desired line at once. It is possible that, in plotting the points established by observation, they may be found to assume, approximately, a curve. The lines, such as *EF*, may then be drawn as tangents to this curve, and when the corresponding equation of line, *CD*, is found, the latter line is tangent to a new curve at the corresponding value of log. h.

Mr. Lyman's method will be found useful in plotting observations in many kinds of engineering work. It has enabled him to present weir formulas covering a wide range of experiment. His equations and diagrams doubtless will furnish the hydraulic engineer with better tools than have hitherto been provided.

Mr. Robinson. R. B. Robinson, Assoc. M. Am. Soc. C. E. (by letter).—The writer heartily agrees with Professor Lyman—and believes that every Western engineer will—that a legalized standard device and regulations to govern the measurement of water in flowing streams are very much needed, and that such device and regulations should be of the simplest possible form and construction consistent with correct and practical results. He would also go further, and say that the device and regulations should be designated by Federal statute, in order to avoid possible complications owing to different State localities on the same stream.

If this comment may serve to add in any way toward the accomplishment of Professor Lyman's aims, as set forth in his paper, it will have answered the purpose for which it is written.

AMERICAN SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

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TOPOGRAPHICAL SURVEYS MADE BY THE AMERICAN SECTION OF THE INTERNATIONAL BOUNDARY COMMISSION UNITED STATES AND MEXICO.

Discussion.*

By Messrs. William B. Landreth and W. N. Brown.

William B. Landreth, M. Am. Soc. C. E. (by letter).—The writer, who has had experience on stadia topographical work, some of which he has described,† has read Mr. Follett's paper with much interest. The surveys made in 1900 by the New York State Engineer's Department for the Barge Canal, were of the same general character as those described by Mr. Follett. Mr. Landreth.

The writer had charge of the New York Barge Canal Surveys from Herkimer to near Clyde (114 miles), on the Oswego and Oneida Rivers, and for the Cicero Cut-off.

The base line was measured with a 100-ft. steel tape under uniform tension, corrected for temperature, and the leveling was done by duplicate lines run forward and back, using ordinary Wye-levels and New York or Philadelphia rods, with an allowable error of 0.05 ft. $\sqrt{\text{miles}}$ between points. The topography was taken by stadia for 2-ft. contours, and plotted on scales of 1 in. in 3 000 or 1 in 1 500. Wash-drill borings were made at short intervals along both land and stream lines, and cross-sections of streams and lakes were made by soundings. The totals of the various classes of work performed and the cost thereof are shown in Tables 18 and 19.

*This discussion (of the paper by W. W. Follett, M. Am. Soc. C. E., published in the October, 1913, *Proceedings*, and presented at the meeting of December, 3d, 1913), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† *Transactions*, Am. Soc. C. E., Vol. XXXIV, p. 281, and Vol. XLIV, p. 92.

Mr. Landreth.

The character of the country and the cost of taking the topography varied greatly in different localities. Along the Erie Canal, from Herkimer to Grove Spring, the country was mostly cleared farm lands, with a large number of buildings in the villages and cities. The territory on the Cicero Cut-off, and between the mouth of Crusoe Creek and the western end of the Division, was open, cultivated land, but the Seneca and Oneida Rivers were generally bordered by woods or swamps. Work in the Montezuma Marshes was slow, owing to high reeds and soft ground.

TABLE 18. NEW YORK BARGE CANAL, MIDDLE DIVISION, 1900. STATEMENT OF FIELD AND MAP WORK, TOTALS.

Location.	Length of transit line, in miles.	Miles of double level line.	Miles of single level line.	Stadia Work.			Ranges sounded.	Map Work.	
				Square miles.	Acres.	Shots per acre.		Sheets.	Scale.
Erie Canal Line	25.84	25.84	80.80	8.26	5 286.4	3.1	....	36	1—1 500
Oneida River Line	.....	.....	.....	1.69	1 083.5	2.7	118.	4	1—3 000
Seneca River Line	53.27	53.27	141.05	16.23	10 385.3	1.8	722.	28	1—3 000
Cicero Cut-off	13.54	.....	18.90	6.52	4 172.8	1.2	....	10	1—3 000
Onondaga Lake	.....	.....	.....	1.35	863.4	2.2	68.	6	1—3 000
Oswego River Line	.....	2.89	5.78	0.39	249.6	6.4	80.	2	1—3 000
Totals, Middle, Division	92.65	82.00	246.53	34.44	22 041.0	2.9	988.	86	....
Herkimer-Utica Line	12.43	12.43	35.47	2.20	1 410.6	8.0	....	14	1—1 500
Totals, all lines	105.08	94.43	282.00	36.64	23 451.6	....	......	100	....

TABLE 19.—COST OF FIELD WORK, EXCLUSIVE OF HEAD OFFICE.

Class of work.	Cost per mile.	Cost per square mile.	Cost per mile of stream.
Transit line	$29.11	....	......
Duplicate levels	25.70	....	......
Single levels	8.82	....	......
Stadia work	......	$175.45	......
Soundings	......	....	$26.86

Accuracy and Cost of the Work.—The running error on the transit lines, as determined by Polaris observations, was as follows, observations being taken about 5½ miles apart:

Line "A", Utica to Grove Spring:

Maximum running error	9′ 25″
Minimum " "	5′ 56″
Average (of 4) running error	7′ 37″

Mr. Landreth.

Line "B", Three Rivers to ¼ Mile East of Clyde:

Maximum running error..............	12′ 30″
Minimum " "	0′ 00″
Average (of 9) running error..........	5′ 08″

Line "C", Herkimer to Utica:

Maximum running error..............	8′ 30″
Minimum " "	6′ 00″
Average " "	7′ 15″

On the leveling, the limiting value of C in the equation error, $C\sqrt{\text{miles}}$ between benches, was 0.050, and the actual values were as follows:

Between Herkimer and East Line of Oneida County:

1.—Between Benches:	Distance, in Miles.
a—Maximum value of C = 0.016	0.40
b—Minimum " " " = 0.001	0.99
c—Average " " " = 0.005	12.56

2.—From Origin:	Miles from Origin.
a—Maximum value of C = 0.0078	4.71
b—Minimum " " " = 0.0000	8.14
c—Average " " " = 0.0027	12.56

Between East Line of Oneida County and Grove Spring:

1.—Between Benches:	Distance, in Miles.
a—Maximum value of C = 0.031	0.9
b—Minimum " " " = 0.0034	6.03
c—Average " " " = 0.013	25.74

2.—From Origin:	Miles from Origin.
a—Maximum value of C = 0.030	0.90
b—Minimum " " " = 0.001	11.00
c—Average " " " = 0.008	25.74

Between Phœnix and Clyde:

1.—Between Benches:	Distance, in Miles.
a—Maximum value of C = 0.034	1.81
b—Minimum " " " = 0.000	2.84
c—Average " " " = 0.009	51.40

2.—From Origin:	Miles from Origin.
a—Maximum value of C = 0.042	6.77
b—Minimum " " " = 0.007	51.40
c—Average " " " = 0.015	51.40

About half the levels on the line between Phœnix and Clyde were run over very soft ground and through swamps.

Mr. Landreth.

Twenty-three stadia circuits run by Party A give a fair example of the results obtained in the stadia work, as follows:

Average length of circuits	5 214 ft.
" number of stations occupied	7
" running error in azimuth	1′ 21″
" " " " " per angle	11.4″
" error in elevation	0.19 ft.
" " " circuit 1	1 214 ft.
Maximum " " " "	823 "
Minimum " " " "	2 424 "

The cost per acre was 84 cents, for transit line, duplicate levels, stadia work, soundings, map work, superintendence, and purchase of supplies, but exclusive of the cost of borings.

The field work on the Cicero Cut-off, a cross-country line 13.54 miles long, covering 4 700 acres, cost 27 cents per acre, exclusive of cost of instruments, equipments, or borings, but including the reduction of all field notes ready for plotting.

The total cost of borings, including cost of outfit, superintendence, and a storehouse, was $10 672.41 for 14 874 ft. penetrated, or 72 cents per ft.

The cost of the map work was $121.60 per sq. mile.

Undoubtedly, the number of stadia shots per square mile is a principal factor in determining the cost of stadia surveys, as shown by Table 20.

TABLE 20.

Survey.	Barge Canal, Middle Division.			
	A.	B	C.	D
Area, in square miles	13.00	11.60	4.20	11.20
Shots per square mile	2 217.00	1 210.00	461.00	960.00
Cost " " "	$257.54	$214.69	$76.39	$161.36

Varying conditions of woods, hills, streams, houses, etc., make it very difficult to predict the cost of stadia work, but the foregoing data may serve as a guide to engineers contemplating work of similar magnitude.

In 1901, the writer had charge of running a line of spirit levels to connect the various lines previously run by the U. S. Deep Waterway Commission, or the 1900 Barge Canal Survey, to furnish continuous lines of bench-mark elevations along the proposed Barge Canal between Albany and Buffalo, Syracuse and Oswego, and from Albany to White-

hall at the head of Lake Champlain, and on those portions of the Erie Canal not covered by the former surveys. Mr. Landreth.

His report thereon was published in the 1901 Annual Report of the State Engineer, Edward A. Bond, M. Am. Soc. C. E. In order to make the results available, the following extracts are taken from the State Report:

"Work in the field was begun at the old grist mill bench mark at Greenbush March 1, 1901, and completed to Herkimer June 20th. Check lines between the Barge Canal benches on the Seneca River and the old benches on the Erie Canal were run at Syracuse, Peru, Weedsport and Montezuma between June 20th and July 7th. From July 7th to August 17th a portion of the party was employed in the Albany office working up the results of the field work. A single line of levels was run on the Champlain Canal from Watervliet to Whitehall between August 17th and September 14th, and duplicate lines from New London to Clyde along the Erie Canal between September 16th and December 10th."

* * * * * * * * *

"The party was constituted as follows: recorder, instrument-man, two rodmen, and a bubble tender. The chief of the party acted as recorder, or, instrumentman as the necessities of the case required."

* * * * * * * * *

"Instruments, Rods and Appliances.

"The instrument used was a Gurley 'Y' level, purchased in 1900 for the Barge Canal survey. The dimensions of the instrument were:

"Focal length ....16½ inches.
Clear aperture of objective.......... 1¼ inches.
Magnifying power ....35 diameters
Value of one division of level bubble
(measured) ....7.04 seconds.
Value of one division of level bubble
as given by makers..........10 seconds."

* * * * * * * * *

"The rods used were improved Gurley New York rods having a special target and folding disc plumbing level. The face of the target had a black background with a narrow white band along its median horizontal line. The white bands were one-fourth of an inch wide at the outer edges of the target, narrowing down to one-thirty-second of an inch at the center of the face, and allowed a closer setting of the target than the older form of targets.

"The rods were divided into feet, tenths and hundredths, and were read to thousandths by a vernier on the target. The foot of the rod was a bronze casting terminating in a truncated pyramid one-half an inch square."

* * * * * * * * *

"Steel pins, twelve inches long, one inch square at the top, tapering to a point and having a shoulder three inches long carrying a hardened steel cone were used for turning points. The pin was driven securely in the ground with a mallet, striking on the head, and the rod was held on the hardened steel cone, care being taken not to disturb the

Mr. Landreth. pins in any way until all readings were taken. The level was shaded at all times by an umbrella when set up, and a cloth bag when moving from point to point. A canvas wind breaker, ten feet long and five feet high, was stretched between one and one-half inch gas pipes driven firmly into the ground."

Duplicate lines of levels were run forward and backward and the limit of the error of closure of the two runnings was 0.020 ft. $\sqrt{\text{distance in miles between benches}}$, from Albany to Herkimer, and 0.016 ft. $\sqrt{\text{distance in miles between benches}}$, on all other lines along the Erie Canal.

"Procedure of Work.

"Starting from a bench or turning point, the instrumentman paced along the towpath from 200 to 250 feet and set up the level, protecting it by the umbrella and wind shield as occasion required.

"Rodman No. 1 remained at the bench and rodman No. 2, starting at the same bench, paced to and beyond the instrument till he reached a point as many paces beyond the instrument as the instrument was from rod No. 1, at which point he drove the steel pin.

"Having carefully leveled the instrument, the leveler set the target on rod No. 1 as a backsight, and then, avoiding both haste and delay, turned the telescope to rod No. 2, and set the target as a foresight. The bubble tender kept the bubble constantly in the middle of the tube by slight pressure of the fingers on the leveling plate of the instrument. To balance errors due to defective vision of the bubble tender or differences in the light on the bubble, the bubble tender moved around the tripod when the telescope was turned.

"The recorder remained with rodman No. 1 until both he and the rodman had read, recorded and checked the rod reading, when he walked rapidly to pin No. 2, checking the paced distances on the way. The recorder then read, recorded, and checked the reading of target No. 2 and signaled 'all right' to the instrumentman, who repeated the signal to rodman No. 1, when they both moved forward. Rodman No. 1, going to rod No. 2, read, recorded, computed and compared results with rodman No. 2 and the recorder, the leveler having at the same time paced up to point No. 2 to check the pacing and then paced past point No. 2 the proper distance and set up the instrument. Rodman No. 1 paced up to the instrument from point No. 2 and then an equal distance beyond it and drove steel pin and set target. Thus this alternation occurred: First set up, rod No. 1 on backsight is set first and rod No. 2 on foresight is set last; on second set up, rod No. 1 on foresight is set first and rod No. 2 on backsight is set last."

* * * * * * * * *

"The length of line run each day depended almost entirely on the wind and the condition of the atmosphere, and work was stopped when it was found that three or more readings were necessary in order to obtain two readings within two-thousandths foot of each other. The best results were obtained by sights of from 200 to 225 feet. The progress records for the various portions of the survey are given in Table No. 2.*

* Rearranged and reproduced herewith as Table 21.

TABLE 21.—BARGE CANAL LEVELS, 1901.

Mr. Landreth

Location.	Days in field.	Miles of single line.	Miles of finished line.	Miles of single line per day.	Cost, per mile, for field work of finished line.
Greenbush-Herkimer	77	343.03	95.43	3.16	$27.70
Grove Spring-Clyde	57	199.18	74.93	3.49	30.90
Tie Lines	4	12.50	5.75	3.12	28.00
Oswego Canal	5	16.60	8.00	3.32	19.38
Champlain Canal	19½	73.26	.....	3.8	11.12

"Accuracy of the Work.

"Table No. 8* has been prepared to show the differences between the east and west lines of this survey. In that table column 1 gives the serial number of the bench mark; column 2 the distance of the second bench noted in column 1, in miles from Greenbush; columns 3, 4, and 5, the difference between the bench marks as given by the west line, the east line and the mean thereof; column 6 shows the partial excesses obtained by subtracting the difference of elevations as determined by the west line from those determined by the east line; column 7 shows the total excess up to that bench mark, the total excess being the algebraic sum of all of the preceding partial excesses. In columns 6 and 7 the plus sign denotes that the east line is above the west line, and the minus sign the reverse. Columns 8 and 9 give the value of 'C' in the equation error $= C\sqrt{\text{miles between benches}}$, between successive benches and from the Greenbush bench respectively.

"Dividing the line from Greenbush to Buffalo into circuits according to the individual surveys and taking the values of 'C' from column 8, as calculated between successive bench marks, as being the severest test of the accuracy of the work, we have the following table:†

TABLE 22.—RESULTS OF LEVELS, 1900 AND 1901.

Circuit number.	Length in miles.	Location	Allowable value of "C."	Maximum. "C."	Times zero occurred.
1	95.42	Greenbush to Herkimer	0.020	0.016	43
2	12.56	Herkimer-East line Oneida County	0.050	0.016	2
3	25.74	East line Oneida County to Grove Spring	0.050	0.045	0*
4	74.93	Grove Spring to culvert east of Clyde	0.016	0.016	10
5	56.7	Culvert east of Clyde to Rochester	0.050	0.049	6
6	94.19	Rochester to Buffalo	0.050	0.038	11

* Minimum = 0.001.

Taking by themselves the separate circuits given in Table 22, and comparing their east and west lines, shows their divergence, as in Table 23.

* Not reproduced in this discussion.

† This refers to Table No. 6 of the original report: the greater part of it is reproduced herewith as Table 22.

Mr. Landreth.

TABLE 23.—DIVERGENCE OF LINES OF CIRCUITS.

Circuit.	Maximum divergence, in feet.	Times zero occurred.
1	0.067	15
2	0.014	4
3	0.050	4
4	0.063	4
5	0.193	2
6	0.135	9

For the line from Albany to Buffalo, 354 miles long, the total divergence was $0.276 - C = 0.014$.

"Lines Re-Run.

"The lengths of the lines re-run varied somewhat on the various surveys, owing mainly to their having been run in different seasons of the year, and during the work of 1901, the amounts re-run were: Between Greenbush and Herkimer, 26 per cent.; between Grove Spring and Clyde, 30 per cent. of the total length of east and west accepted lines."

* * * * * * * * *

"The men employed on the Barge Canal lines were taken from the State Civil Service list, and had no special training in accurate leveling, though the men employed in 1901 nearly all had experience in similar work in 1900.

"The instruments used were the regular engineer's levels with sensitive bubbles, but could in no sense be called 'precise levels', as the term is used in Government reports.

"The results are those obtained by men of average ability and carefulness working under rigid instructions with instruments such as may be obtained from any reputable maker, and it should be distinctly understood that no claim is made that the lines run are 'precise levels' in the technical sense of the term.

"The methods of work were almost identical with the later methods of the U. S. Coast Survey and of the U. S. Geological Survey but the levels used were inferior to the precise levels used by the latter in the optical power of the telescope, in weight and solidity and of a much lower cost. The results are those obtained with an average leveling party working at a good rate.

"Experience gained on the Barge Canal surveys shows the necessity of certain precautions to secure a uniform degree of accuracy. Among them may be cited the following:

"1. Before testing the instrument adjustments it should be set in the shade and allowed to remain a few moments, in order to allow all of its parts to come to the same temperature.

"2. During bright sunlight the line of sights should not be near the ground, or a fence, stone wall or building, to avoid the action of the heat radiated from them.

"3. After the target is set and clamped another careful observation should be made of the contact of the rod with the turning point,

the plumbing of the rod and the centering of the instrument bubble before the final acceptance of the target setting. Mr. Landreth.

"4. During windy weather the instrument should not be set up in dry sand or dust, as the vibration of the tripod legs causes fine particles to settle under them, raising the instrument.

"5. After the instrument is leveled the observer and bubble tender should stand near it as little as possible, owing to the effect of the heat of their bodies in changing the temperature of parts of the instrument. They should, as far as possible, place their bodies so that their breath will not be blown upon the instrument.

"The essentials for obtaining good results are: A good instrument with a sensitive bubble, kept in perfect adjustment; equal back sights and fore sights; protection of the instrument from the direct rays of the sun at all times; cessation of work when bad air or wind does not allow two settings of the target on the same point within 0.002 of a foot. The chief of the party should be a careful, patient man, who should early learn when to stop work, and his guide should be accuracy first, speed second."

W. N. Brown, M. Am. Soc. C. E. (by letter).—Mr. Follett advances certain views concerning the accuracy of the stadia and its limitations. Although they may be true as applied to this special piece of work and the methods therein used, they are certainly far at variance with the writer's experience, and are not applicable to stadia work in general. The author fails to appreciate the accuracy with which stadia measurements are being made. Under the heading "Use and Abuse of Stadia", Mr. Follett states: Mr. Brown.

"In any work where a variation of 1 or 2 m. in the relative location of points near together, or 5 or 6 m. in that of those which are material distances apart, can be tolerated, the stadia offers a most rapid and handy method of work."

If Mr. Follett had said feet, instead of meters, he would have been much nearer the accuracy attainable in stadia measurements. The source of his error is in the type of rod used. His results were probably as good as could be obtained with that rod, whether $(f + c)$ and stadia factor corrections were applied or not. That the rod was not capable of close reading is indicated in his statement: "As the nearest that the stadia interval can usually be read, at distances of about 200 m. or more, is to the centimeter, which means a meter in distance". During the past year the writer has had a number of topographic field parties under his direction on the Topographic Survey of Cincinnati. (Area 100 sq. miles, scale of map, 400 ft. to 1 in.) In carrying out this work approximately 1 650 miles of stadia traverse have been run—in street location and across country—filling in topography. This traverse was controlled by triangulation, so that the accuracy of the stadia measurements was always under observation and determined by each closure on control points. One of the specifications for this work was:

Mr. Brown.

"All horizontal distances between well-defined points must scale correct to within the smallest distance which it is possible to plot on the map. This distance is 1/80 of an inch, representing 5 ft. on the ground."

This did not apply to short distances alone, but to distances between points anywhere on the map. That this condition was met is shown by numerous tests to which the map has been subjected by the Department of Sewerage Investigation, City of Cincinnati, before acceptance of the work from the contractors (the work was done by contract).

On this work, rods 3 in. wide and 12 ft. long, divided to feet, tenths, and hundredths of a foot, were used. It was found that, up to 200 ft., the intercept could be read to the nearest half division on the rod, representing ½ ft. in distance; and, up to 600 ft., the intercept could be read to the nearest division on the rod representing 1 ft. in the distance. The length of sight was kept less than 600 ft., as far as possible, especially on long traverse lines.

When reading distances to the nearest foot, instead of the nearest meter or two, the necessity of applying corrections for stadia factor and $(f + c)$, which often amount to as much as 2 ft. in 100 ft. of measured distance, becomes apparent.

Although the need of rod levels is not so apparent on level ground, it is nearly impossible for a rodman to hold the rod truly vertical on a steep slope, as a very slight inclination either way will change the intercept on the rod one or two hundredths, thus introducing a corresponding error of 1 or 2 ft. It certainly seems advisable to have such levels, so that they may be used when necessary.

It is seldom that one finds an instrument in which the ratio of the distance intercepted on the rod to the distance being measured is exactly 1 to 100. Out of eleven stadia instruments used on the Cincinnati work, three had the wires placed so accurately that this ratio was true up to 800 ft. The eight remaining ones required corrections varying from 0.75 to 3 ft. per 100 ft. of distance. They were a fairly representative group of instruments: Seven were by Bausch and Lomb, three by W. and L. E. Gurley, and one by Young and Sons.

It would seem that the condition of a number of instruments without stadia factor, as found by Mr. Follett, is exceptional. The question naturally arises: Was this not partly due to the fact that his rods were not adapted to close or nearly exact reading, and may not some of his "variation of 1 or 2 m. in the relative location of points near together", be undetected stadia factor crying for recognition?

Far from agreeing with Mr. Follett that the stadia is too inaccurate for satisfactory use in the better class of land surveys and in city and town surveys (meaning topographic surveys; for manifestly it is not applicable in city land surveys where land is so valuable that discrepancies in distance of 0.1 ft. are of serious moment), it is the writer's belief

that the stadia can be used without any injury to the accuracy of the results, wherever these results are to be plotted on a scale of 50 ft. to 1 in. or smaller scales. In other words, the errors of plotting on a scale of 50 ft. to 1 in. are just about equal to the errors of stadia measurements when properly carried out, and the necessary corrections for stadia factor, focal length, etc., are applied. Of course, with stadia as well as with any other method, there must be proper primary control. Mr. Brown.

Relative to cost, Mr. Follett gives $39 per sq. mile, adding that this "is not properly comparable with contour surveys which cover all the ground with equal thoroughness. Such may cost two or three times as much per square mile as did this and still be economically done". The writer is afraid that this is misleading and will cause many an engineer to underestimate greatly the cost of topographic surveying, if he uses even ten times this cost as a maximum. There are so many conditions affecting the costs of topography that it is dangerous indeed to hazard even a guess until the individual conditions are very thoroughly examined. The elemental conditions affecting costs are:

(*a*) The scale on which the map is to be plotted;

(*b*) The degree of accuracy to be maintained;

(*c*) The physical conditions of the area, affecting cost both of control and topography, such as quantity of brush, steepness of slope, and inaccessibility;

(*d*) The amount of culture, and of traffic interference, the latter being especially important in considering city work.

It is the writer's opinion that topography may cost from $30 to $1 500, or even $2 000, per sq. mile, depending on these varying conditions, and still be most economically executed.

MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

CHARLES ARTHUR HAGUE, M. Am. Soc. C. E.*

Died June 26th, 1911.

Charles Arthur Hague was born at Newton, Mass., on October 9th, 1849.

He was in the employ of the Clapp and Jones Manufacturing Company at Hudson, N. Y., as a Draftsman and Designer, from 1872 to 1875, when he resigned to become Mechanical Engineer and Draftsman on steam engines and boilers for the Frank Douglas Machinery Company, of Chicago.

In 1876, Mr. Hague became Master Mechanic for the Furst and Bradley Manufacturing Company, and while in that position he patented many improvements on plows and other implements, besides designing and erecting numerous special machines. From 1884 to 1887, he was Superintendent for the E. P. Allis Company, of Milwaukee, Wis.

After one year with the Knowles Steam Pump Company, of New York City, he became Mechanical Engineer for the H. R. Worthington Company, which position he held until 1895. From that time until his death, he was engaged in consulting practice in New York City.

Mr. Hague was the author of a treatise entitled "Pumping Engines for Water Works." He was a member of the American Society of Mechanical Engineers, the American Water Works Association, and the New England Water Works Association.

Mr. Hague was elected a Member of the American Society of Civil Engineers on February 3d, 1892.

GEORGE WILLIAM LEE, Assoc. M. Am. Soc. C. E.†

Died January 6th, 1911.

George William Lee was born on June 10th, 1875, at New Haven, Conn. He was the son of George W. and Harriet (Chappel) Lee, of East Lynn, Conn., where for five generations their ancestors had lived. He was educated at the Bordentown Military Institute, Worcester Academy, and Worcester Polytechnic Institute.

* Memoir prepared by George A. Orrok, M. Am. Soc. C. E.

† Memoir prepared by William R. Hill, M. Am. Soc. C. E.

Mr. Lee's whole life was devoted to his Profession, even during his school vacations, for in the summer of 1894 he was engaged on surveys near Winchester, Conn.; in 1895 on surveys for the improvement of the water supply of Athol, Mass.; and in 1896 on surveys for a sewerage system for Hyde Park, Mass., and a water supply for Billerica, Mass.

In 1897 he finished his course at the Polytechnic, and was then engaged by William Barclay Parsons, M. Am. Soc. C. E., and placed in charge of a party making surveys for the Subway in New York City, after which he was with a corps of engineers, U. S. A., on surveys for military roads in Porto Rico.

In August, 1901, Mr. Lee was engaged as Engineer for Sundstrom and Stratton, General Contractors, and remained with this firm until his death, at which time he was Chief Engineer. He showed marked ability in designing plant and directing the construction of many structures. While thus engaged the most important work under his supervision was on the New York Central and Hudson River Railroad, in constructing the Oak Grove and DeWitt Yards, double-tracking the Fall Brook Division and the Peekskill Tunnel on the main line, the Chateaugay Branch of the Delaware and Hudson Company, and Contract No. 3 of the New York State Barge Canal, at Fort Miller, N. Y. His devotion to his work won the admiration of all with whom he came in contact.

He is survived by his wife, Rhoda Hoyt Lee, and two daughters, Harriet E. and Dorothy C. Lee.

Mr. Lee was elected a Junior of the American Society of Civil Engineers on March 4th, 1902, and an Associate Member on January 2d, 1907.

PAPERS IN THIS NUMBER

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"A STUDY OF FLUID RESISTANCE." LUTHER WAGONER.

"A STUDY OF ECONOMIC CONDUIT LOCATION." C. E. HICKOK.

PAPERS AND DISCUSSIONS CURRENT IN PROCEEDINGS

"**Shearing Strength of Construction Joints in Stems of T-Beams, as Shown by Tests.**" LEWIS J. JOHNSON and JOHN R. NICHOLS...........Feb., 1913

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"**Concrete Bridges: Some Important Features in Their Design.**" WALTER M. SMITH, SR., AND WALTER M. SMITH, JR...........Aug., "

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"**Topographical Surveys Made by the American Section of the International Boundary Commission, United States and Mexico.**" W. W. FOLLETT...........Oct., "

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"**Storage to be Provided in Impounding Reservoirs for Municipal Water Supply.**" ALLEN HAZEN...........Nov., "

"**The Depreciation of Public Utility Properties as Affecting Their Valuation and Fair Return.**" JOHN W. ALVORD...........Nov., "

"**Painting Structural Steel: The Present Situation.**" A. H. SABIN. (To be presented Jan. 7th, 1914.)...........Nov., "

"**Stresses in Wedge-Shaped Reinforced Concrete Beams.**" WILLIAM CAIN...........Nov., "

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